# SMALL GRAINS IN RECLAMATION OF PHOSPHATIC SETTLING POND CLAYS IN SOUTH CENTRAL FLORIDA

BY

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Dedicated to my wife Jean
our children Randy Karen Tracey and Brad
and my sister-in-law Veronica

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Phosphate mining in Florida has generated approximately 48,000 hectares of phosphatic settling-pond clay areas in Polk County Florida law stipulates that land disturbed by mining must be reclaimed These clay areas could be used to produce feed grain for the Florida livestock industry Phosphatic clays are very fertile and demonstrate good crop productive capacity Florida 301 wheat (Triticum aestivum cm Thell) and Florida 201 triticale (X Triticosecale Wittmack) were investigated for their yield potential in the Polk County phosphatic clay environment in the 1986 87 (S1) and 1987-88 (S2) growing seasons Studies included (a) the influence of planting dates early (EP) and late (LP) on grain (GYD) and biomass (BYD) yields, and effective grain filling duration (EGFD), and (b) BYD, GYD and grain quality response to N levels (0, 56, 112 168 and 224 kg ha$^{-1}$)

EGFD averaged 9 5 and 9 days longer for wheat and triticale, respectively over the two growing seasons relative to LP treatments High temperatures in S2 caused abrupt termination of kernel dry matter accumulation The positive and significant ($p < 0.01$) correlation ($r^2$ range 0 63 to 0 90) between days after anthesis and DM accumulation indicates that GYD would be increased by longer filling period Also the significant ($p < 0.01$) and positive ($r^2 = 0.42$) correlation between BYD and GYD over both seasons and in S2 ($r^2 = 0.62$) suggests that morphological developments during the vegetative period influences GYD outcome Overall yield response was effected by environmental conditions in S1, but in S2 all variables except harvest index (HI) were higher for EP treatments in both crops In S2, GYD was > 3000 and BYD was > 6000 kg ha$^{-1}$ for EP treatments compared to GYD of < 2000 and BYD < 6000 kg ha$^{-1}$ for LP treatments

High residual N from alfalfa (Medicago sativa L.) masked the response to applied N in S1 In S2, GYD and BYD of over 3000 and 8000 kg ha$^{-1}$, respectively were obtained at the 112 kg ha$^{-1}$ N rate Highest GYD of 1160 and 1100 kg ha$^{-1}$ to incremental N was at the 56 and 112 kg ha$^{-1}$ N rate for wheat and triticale respectively Test weight for wheat and triticale at the 112 kg ha$^{-1}$ N rate was 79 5 and 66 7 kg hl$^{-1}$ respectively The 112 kg ha$^{-1}$ N rate also gave highest numerical dollar value net returns on N cost Percentage grain protein increased with incremental N application for both crops over both growing seasons and ranged from 14 1 to 14 1 in S1 and from 9 9 to 15 7 in S2

# CHAPTER 1
# INTRODUCTION

Approximately 48 000 hectares of mined-out settling pond clay areas now exist on phosphate-mined land in Polk County Florida It is also estimated that this area will increase about 66% by the year 2000 (Woods, 1984 Stricker, 1988) These settling ponds which are the disposal sites for the clay, the rejected portion of the mined ore after the beneficiation process (Harwood 1982 Lamont et al 1975) have for some time been of great concern to residents and administrators of the county This concern is mainly due to the objectionable "moonscape" appearance they give to the landscape (Baxter 1969) thereby reducing the value of the land (Stricker, 1988, Newborn 1986) Concomitant with this situation is the inevitable adverse impact on the county's economy when mining operations terminate there in the future (Hood et al 1984) Reclamation of these clay areas through production of agricultural crops, such as small grains, will improve their aesthetic appearance and value, simultaneously contributing to the county's economy (Hochmuth et al 1987 Stricker, 1988)

## Historical Origin of Phosphatic Clays

Florida's "grey gold" as the phosphates were called, were discovered by two bear hunters in 1881 (Baxter, 1969 Grace, 1954) Polk

County known as the "bone valley" which had the richest ore deposit, about 83 kilometers long by 67 kilometers wide (Anonymous, 1974; Cross 1973; Bloomquist, 1982) became the second phosphate center of Florida having succeeded to Dunnellon (Burnett, 1976). Phosphate deposits are the result of a process of mixing and compaction of phosphate sand and clay in equal parts called "matrix". This process took place during the Pliocene age approximately twenty million years ago (Vondrasek, 1982; Bloomquist, 1982).

Mining in central Florida began as a pick and shovel operation in the early stages. However since the second world war the demand for phosphate for inorganic fertilizer (nationally and internationally) and other industrial uses such as food preservatives, toothpaste, animal feeds, vitamin and mineral capsules, etc. has led to a tremendous increase in mining operation, producing over one million tons of ore annually, thereby generating massive quantities of dilute phosphate clay (Flittman and Sweeney, 1983).

The phosphate matrix lies approximately 3.0 to 15.5 meters below the earth's surface. Mining is accomplished by using large electrical draglines to remove the "overburden" which is cast aside. The matrix is then removed and placed into a previously excavated pit. High pressure water jets are then used to break down the matrix material into a slurry which is then pumped to a "beneficiation" plant where the phosphate and sand are removed, leaving the clay fraction. This rejected slurry, consisting of 2 to 6% solids, is pumped to various settling ponds (each 120 to 320 hectares in size) for consolidation. The water is collected and reused in the "beneficiation" process. However, the clay portion is

systematically left to dry and in order to fill the previously excavated cavity (Bloemquist, 1982; Pittman and Sweeney, 1983; Hmad et al., 1984; Grete, 1954; Berr, 1932).

## Characteristics and Properties of Phosphatic Clays

Phosphatic clays have very slow settling rates and very high water-holding capacities. This is mainly due to their very fine particle size. Collectively, phosphatic clay is composed of particles of clay, quartz and phosphate material rejected during the "beneficiation" process, which have an average size of 0.3 micron. A typical settling pond may take up to 20 years to completely solidify (Bloemquist, 1982; Vondracek, 1982; Lamont et al., 1975; Pittman and Sweeney, 1983). The primary mineral components of phosphatic clays are montmorillonite, polygorskite (attapulgite), illite and kaolinite. Montmorillonite is the most common mineral. Both montmorillonite and attapulgite have a very high affinity for water, hence the high water-holding capacity of these clays. Phosphatic clays have a plasticity index ranging from 70 to 150 and are classified as very plastic (Bloemquist, 1982; Bromwell, 1982; Harwood, 1982). These properties cause phosphatic clays to become very gluey and sticky when wet or very hard and clotty, and develop large cracks when dry (Stricker, 1980; Hochmuth et al., 1987). This, of course, presents a management problem for agronomic practices. Phosphatic clays are very high in plant nutrients such as P, Ca, and Mg and also have moderate quantities of potassium. The pH of the clays range from 7.2 to 7.8 (Hilsky et al., 1980; Bromwell, 1982; Hochmuth et al., 1987). The high nutrient content makes these clays highly suitable for agriculture.

## Settling Pond Reclamation

Since July 1975, Florida law has made it mandatory that all lands disturbed by phosphate mining be restored (Hochmuth et al., 1987). As a consequence, the Florida Institute of Phosphate Research (FIPR) was established and became responsible for research on phosphatic clay (Pittman and Sweeney 1983). Agricultural use of the land for instance was a major area to be considered (Carlenger and Fulelhan, 1983). If manageable, the high pH, good water holding capacity (which would reduce irrigation needs) and good fertility of the clays would make crop production on them an attractive economic venture.

To this end The Mined Lands Research/Reconnection Project which is a joint effort of Polk County Board of Commissioners, University of Florida (IFAS), Florida Institute of Phosphate Research (FIPR), Polk Soil and Water Conservation District and the phosphate industry, was established in October 1985 (Woods, 1986, Hochmuth et al., 1987). The main objectives of this project are to (a) carry out research and (b) commercially demonstrate the production of various agricultural crops (such as grain, forage and vegetables) and cropping systems on phosphatic clays.

## Economic Importance of Small Grains

The high amino acid (protein) content of small grains has made them very valuable in livestock (including poultry) feeding programs (Myer et al., 1987). A protein content of 12% to 16% is desirable in small grains used for animals feeds (Hunter and Stanford 1973).

Lysine is one of the most important amino acids required in feeds A major objective in the development of triticale (X Triticosecale Wittmack) was to combine the lysine content of rye (Secale cereale L.) with the yield and productivity of wheat (Triticum aestivum em Thell) Myer and Barnett (1987) tested wheat of 14.7% and 18.2% crude protein values in swine diets They reported that because of its high lysine content, wheat could replace all the corn and part of the soybean (Glycine max L ) in the diet Myer et al (1982) stated that wheat is equivalent to corn (Zea mays L ) in metabolizable energy and that wheat also had higher phosphorous content Ruiz et al (1987) reported that broiler chicks fed on wheat (Florida 301) and triticale diet showed numerically greater feed efficiency and growth response compared to chicks fed on corn and soybean McGinnis et al (1985) also reported that laying hens fed on triticale diet gave results equal to soybean corn diet

Small grain production in Florida is inadequate to supply the feed requirement of the state's livestock industry (Myer et al , 1987) Consequently, over one million head of cattle are shipped out of the state annually for finishing Simultaneously 80% of the beef consumed in the state is shipped in The dairy poultry and swine farmers also depend on out-of state grain for their operations

Utilization of settling pond clay areas to produce small grains would increase the total land area of these crops in the state, provide feed grain for the livestock industry, and help to stabilize the economy of Polk County (Hachmuth et al 1987) A major advantage of small grains is their ability to fit well into multiple cropping systems including double-cropping with summer crops such as grain sorghum (Sorghum bicolor

L.), soybean, or tropical corn (Barnett et al., 1982; Hairston et al., 1987). This practice will increase the production capacity per unit land area and hence feed production on these phosphatic clays. In addition small grains may be used as forage crops (Wright et al., 1983). The objectives of this research were to investigate the production potential of wheat and triticale with respect to (a) their performance in the warmer climate of south central Florida and (b) their nitrogen requirements on phosphatic clays.

CHAPTER 2
YIELD OF TWO SMALL GRAIN CROPS AS INFLUENCED BY
PLANTING DATE ON PHOSPHATIC CLAYS IN A WARMER FLORIDA CLIMATE

## Introduction

A survey conducted in 1982 reported that 160,000 hectares of small grains were grown in Florida. Eighty percent of this was equally grown to wheat (*Triticum aestivum* ss. Thell) and rye (*Secale cereale* L.), the remaining 20% to oat (*Avena sativa* L.) (Barnett et al., 1982). Production of these crops was mainly in the northern section of the state which according to McCloud (1982), is the fringe of their area of adaptation. Since the small grains are temperate annuals (Evans and Wardlaw, 1976; Mislevy et al., 1984), the more tropical climatic conditions of the southern section of the state do not readily permit production (Calhoun, 1986; Kalmbacher et al., 1987). Mislevy et al. (1984) tested small grain crops of wheat, oat, rye and triticale, a man-made intergeneric hybrid which combines the grain yield potential and quality of wheat with the hardiness and high lysine content of rye (Morey, 1979; Barnett and Lukaszewski, 1979; Calhoun and Barnett, 1986; Zillinsky, 1985) for forage production at the Agricultural Research and Education Center (AREC) at Ona, Florida, in the 1983-84 growing season. They reported dry matter (DM) yields up to 8 Mg ha$^{-1}$. From evaluation studies on these small grains at the same location, Kalmbacher et al. (1987) concluded that extreme climatic

conditions in the south Florida environment contributed to the difficulty in producing small grains in the area

The environment strongly impacts the production of small grains (Fisher and Hille&Lambers, 1978; Adjei and Kirkham, 1979; Wardlaw et al., 1980; Bruckner and Frohberg, 1987b). Being aware of this, plant breeders have used stability across environment, as well as performance within a specific environment, as adaptation criteria for selecting small grain crops (Fischer and Maurer, 1978; Calhoun, 1985; Keim and Kronstad, 1979; Heinrich et al., 1983; Nor and Cady, 1979; Campbell, 1987; Bruckner and Frohberg, 1987b). Clarke et al. (1984) suggested that choice of crop should be environment specific and that results from studies conducted in one environment should be confirmed in another.

The main environmental factors affecting the production of small grains are temperature, solar radiation, moisture, soil nutrients, and pests and diseases including weeds (McCloud, 1982; Linville et al., 1987; Prine, 1971; Laing and Fischer, 1977). While direct management activities (such as fertilizer application or plant population arrangement to regulate soil nutrients, soil moisture or light interception (Prine, 1971; Winter and Welch, 1987)) may be used as control measures for most of these factors, a proper understanding of the effects of temperature on plant development is necessary in order to manage the system for best results. Temperature is driven by solar radiation. According to Fischer (1985), crops may experience both temperature and solar radiation regimes, depending on location (climate) and sowing date. This may cause variation in the development of kernel numbers and size. The cereal crops (among as small grains) have distinct stages in their life cycle (Large, 1954;

Zadoks et al 1974; Evans and Wardlaw 1976). The pace and rate of development of these stages is temperature dependant (Weigand and Cuellar, 1981; McCloud 1982) and may effect final yields. Temperature effects on small grain production have been well documented (Fischer 1985; Gebeyehou et al., 1982a, 1982b; Seifield et al 1977; Wych et al. 1982; Weigand and Cuellar, 1981; Worrington et al 1977; Asana and Williams, 1965; Evans and Wardlaw, 1976; Frank et al 1987; Sayed and Ghandorah 1984; Wardlaw et al., 1980). The post-anthesis or grain filling period (GFP) stage 10.5 to 11.3 (flowering to ripening, Large 1954) seems to be the most critical. Grain filling period has been defined by Gebeyehou et al (1982b) as the number of days from anthesis to physiological maturity, and by Knott and Gebeyehou (1987) as the number of days from heading until chlorophyll disappearance from the glumes. This definition is also supported by Weigand and Cueller (1981). High temperatures at this stage will shorten the period, resulting in grain yield reduction (Sayed and Ghandorah, 1984; Fischer 1985; Wardlaw et al 1980). Seifield et al (1977) found that temperature regimes of 15/10°C to 30/25°C day/night shortened the GFP from 60 to 20 days. They concluded that high post-anthesis temperatures in the field would limit grain yields through shortening of the GFP. Weigand and Cueller (1981) reported that each degree rise in temperature (range 15.8 to 27.7°C) resulted in a three-day shortening of the GFP. They concluded that temperatures above normal (15 to 20°C) during this period could result in up to 25% yield reduction. These findings were similar to those of Worrington et al. (1977) who also reported that high temperatures shortened the GFP, resulting in low final grain yields. From earlier studies, Asana and Williams (1965) reported

mean grain yield reduction of up to 16% in wheat for each six-degree rise in daytime temperature between 25 to 31°C

The length of the vegetative phase may impact the GFP and consequently, final yields (Evans and Wardlaw 1976) Munchali (1985) from studies on wheat grown for grain and grazing in North Florida, reported that when grazing caused the vegetative phase to extend into spring temperatures the GFP was shortened resulting in lower grain yields However according to Colville and Frey (1986) high temperatures may reduce duration of both vegetative and reproductive phases Cabeyahou et al (1982b) reported that increased duration of the vegetative period had a positive effect on grain yields

High temperatures are often associated with drought or water stress conditions This may impose growth limitations, such as early plant maturity or premature senescence, resulting in lower yields (Clarke et al 1984, Sayad and Gadalleh 1983, Knott and Cabeyahou 1987) The high water holding capacity of phosphatic clays are advantageous for crop growth and may eliminate the need for irrigation without creating water stress problems However it may also present a problem in terms of executing management operations (Hochmuth et al 1987) Following rains, several days may elapse waiting for perched water to percolate and evaporate before field activity can take place Management operations, such as time of seeding may therefore be delayed This behavior is typical of soils with high clay content In Brazil for example June is the normal time for planting wheat However in certain areas where clay soils predominate perched water from rains may push planting time as much as two months later (Beckman, 1976)

If environmental conditions are favorable, the production of adaptable small grain crops on phosphatic clays in Florida would be advantageous as this would generate economic benefits for both the phosphatic clay communities and the state (Stricker, 1988). However, to date no studies have been conducted on the production of these crops in this particular environment. Consequently the objectives of this study were to investigate the yield potential of small grain crops by (a) evaluating the environment's effect on grain filling duration, grain and forage (biomass) yields and (b) determination of the optimum time for planting.

## Materials and Methods

Field studies were conducted at the Agrico site of the Mined Lands Research/Demonstration Project in Polk County, Florida. The site is located approximately 33 km southwest of the town of Bartow. The geographical location of Bartow is latitude 27°54 N and longitude 81°51 W with an elevation of 38.7 meters above sea level. Average annual precipitation is 431.8 mm and average midnight temperature is 17°C (National Oceanic and Atmospheric Administration, 1987-88). The research area was part of a 200-hectare recently reclaimed phosphatic clay settling pond. Clay samples were taken over the general area for elemental analysis.

Florida 301 (a winter/facultative) wheat and Florida 201 (a spring type) triticale, two small grain crops developed at the North Florida Research and Education Center (NFREC) Quincy, Florida (Barnett and Luke, 1980; Calhoun and Barnett, 1984), were grown on the site over the 1986-87

(S1) and 1987 EE (S2) growing seasons. Before S1 planting, the area was cropped to alfalfa (Medicago sativa L.). The S2 small grain crop was preceded by tropical corn. In both seasons the land was disked, harrowed and power tilled twice to break up clods. In S2 this process was followed by a "mellowing" period. "Mellowing" is a term used to describe a process whereby alternate wetting and drying cycles cause the large clay aggregates (clods) to shrink and crumble into smaller size particles. This allows for a more uniform seedbed.

The experimental design was a split plot with two planting dates, early (EP) and late (LP). Planting dates were main plot and crops were sub plot. The treatment combinations were replicated five times. Planting was on 21 November 1986 and 5 January 1987 for EP and LP in S1 and 10 December 1987 and 15 January 1988 for EP and LP in S2. The later S2 plantings were due to inclement weather which prevented November planting as in S1. The recommended time for planting small grains in North Florida is 15 November to 15 December for wheat, and 25 November to 1 January for triticale (Calhoun and Barnett, 1986, Barnett and Wright, 1986). Each plot had seven rows, each 6.19 m long with 17.5 cm between rows. A grain drill equipped with double disk openers was used for planting. Planting rates were 90 kg $ha^{-1}$ for wheat and 112 kg $ha^{-1}$ for triticale.

Plots were fertilized with 112 kg $ha^{-1}$ of $K_2SO_4$ (to give 50 kg of K and 20 kg of S per hectare) and 112 kg $ha^{-1}$ of nitrogen supplied by $NH_4NO_3$. Nitrogen was applied at early tillering (Large, 1954). Fertilizer was applied with a gandy distributor. Overhead sprinkler irrigation was applied in the early stages to facilitate seedling

emergence and stand establishment Plots were sprayed with Benlate (benomyl) and ceevin (carberyl) both at 1 12 kg ha$^{-1}$ in S1 and with Dithane M45 (manomeeb) at 2 24 kg ha$^{-1}$ and Lannate (methenyl) at 0 95 liter ha$^{-1}$ in S2 to control powdery mildew (Erysiphe graminis DC ) and aphids (Schizaphis graminum Rond ) Climatological data (measured in the township of Bartow) on temperature and precipitation for the experimental period were extracted from publications of the National Oceanic and Atmospheric Administration (NOAA) Solar radiation data were from the AREC at Ona located approximately 42 km southwest of the research site

In both seasons, data were collected on days to anthesis days to harvest days in grain filling period biomass yield grain yield and yield components in S2 tiller height at anthesis was also measured Measurement for GFP was as follows at anthesis 25 spikes were tagged on both ends of each plot Tagging was done 30 cm from either end of the five inner rows in the plot The plots were considered to be in anthesis when 50% (visual estimation) of the spikes in the plot had anthers extruded in the central florets (Gebeyehou et al 1982b Muntholi 1985) Five of the tagged spikes were clipped from each plot weekly until final harvest The spikes were oven dried at 60°C for 72 hours After drying, spikes were weighed then threshed in a spike (hand) thresher The threshed whole kernels were collected electronically counted, and weighed This data was used to determine dry weight accumulation

Final harvests were carried out on April 30 and May 1 for EP and May 27 for LP in S1, and April 28 and 29 and May 19 for EP and LP in S2 The central 3 09 and 4 64 m of the five inner rows from each plot was harvested in S1 and S2, respectively A Jari mower equipped with a sickle

ber was used for harvesting. Plants were cut at a stubble height of approximately 7 to 10 cm. Prior to harvest, spikes were randomly counted from three one-m section of each plot to determine spikes $m^{-2}$ (SPM). Harvested samples were collected and dried in a grain dryer for five days, weighed for biomass, and then threshed with a vogel thresher. Grains were then collected, cleaned, and weighed for yield determination.

Kernels $m^{-2}$ (KM) were determined by dividing the final grain yield $m^{-2}$ by the individual kernel weight at final harvest. This assumes that the kernels in final yield represent those going through the period from anthesis to maturity, thereby eliminating any field or handling losses. This assumption closely mimics the actual situation on a commercial scale. Kernel dry matter (DM) accumulation $m^{-2}$ was then calculated by multiplying KM by the weekly kernel weight (KW) measured during the period from anthesis to harvest.

Grain filling duration was determined as effective grain filling duration (EGFD). This was done as follows: polynomial regression equations up to fourth order were first fitted to the kernel DM accumulation $m^{-2}$ vs. days after anthesis data. The equation with the highest significant order (from the appropriate F test) was then selected as the estimate for the parameter. The data was then fitted to the equation to determine the maximum derivative dw/dt. The derivative was calculated as $w_2 w_1/t_2-t_1$, where $w_2$ and $w_1$ are kernel weight, and $t_2$ and $t_1$ are days after anthesis. This enabled instantaneous determination of dw/dt, where dw = the change in DM accumulation and dt = the change days after anthesis. This derivative (slope), which is the growth rate over the linear phase of kernel development was then divided into the final

grain (kernel) yield $m^2$ to give the EGFD (Gabeyehou et al 1982b Jones et al 1979 Bruckner and Frohberg 1987b Maynard et al 1971, Maynard and Kennengberg 1976 Pfeifer and Egli 1988 Muschall, 1985 Hartung et al 1989)

Analysis of variance mean separation, regression analysis and correlation was carried out where appropriate (Petersen 1977 Gomez and Gomez 1984) using SAS PC program (SAS Software, 1988)

## Results and Discussion

### Growing Conditions

Rainfall temperature and solar radiation for both growing seasons S1 and S2 are shown in Figs 2-1 through 2-8 Total rainfall in November of S2 (Fig 2-2) was 187 96 mm compared to 12 95 mm for the same period in S1 (Fig 2 1) The high rainfall in the early part of S2 made field operations difficult consequently planting was delayed for 18 days compared to S1 Weekly rainfall for the growing seasons (Figs 2-3 and 2 4) were adequate for crop growth The pattern of weekly temperatures was very similar for both seasons (Figs 2-5 and 2 6) There was a tendency for the temperature to fall in the early stages of the growing seasons and then increase towards the end In both seasons, the average weekly temperature was within the range (optimum being 5 to 35°C) for wheat production under tropical conditions (Ruder 1985, Fischer, 1985) The pattern of solar radiation (Figs 2-7 and 2-8) is very similar to that of the temperature i e it increases as the growing season progresses Solar radiation is the driving force for temperature therefore the similarity in pattern is expected

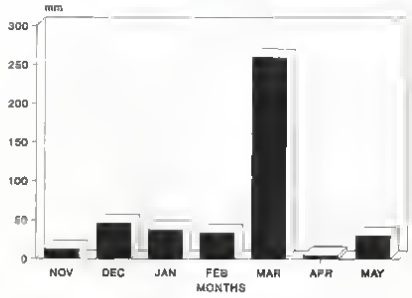


Fig 2-1 Monthly rainfall for the 1986-87 growing season (data from NOAA).

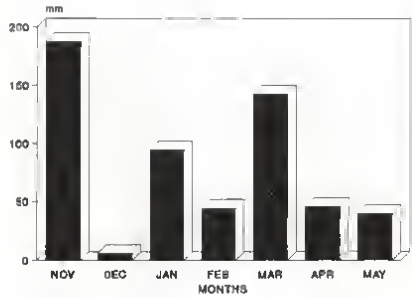


Fig. 2-2. Monthly rainfall for 1987-88 growing season (data from NOAA).

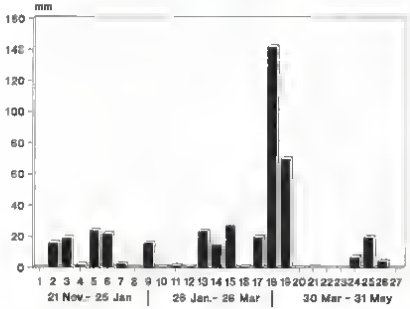


Fig. 2-3 Weekly rainfall for 1986-87 growing season (data from NOAA).

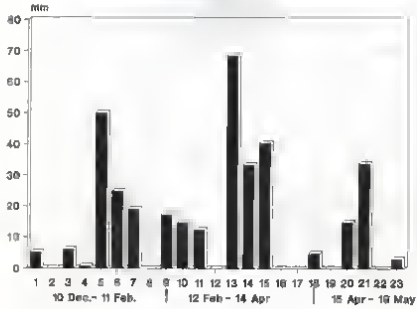


Fig 2-4 Weekly rainfall for 1987-88 growing season (data from NOAA).

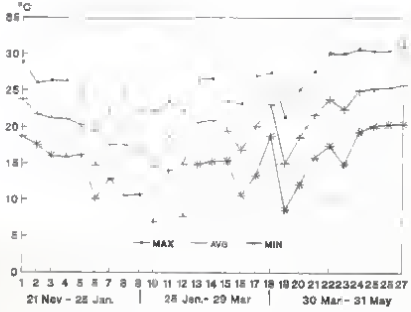


Fig 2-5 Weekly temperature for 1986-87 growing season (data from NOAA)

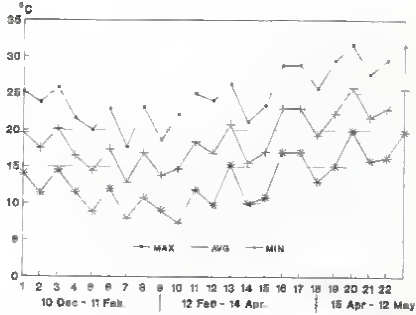


Fig. 2-6. Weekly temperature for 1987-88 growing season (data from NOAA).

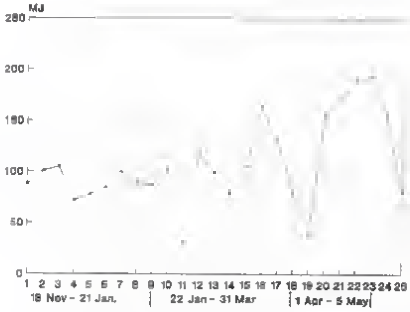


Fig. 2-7. Solar radiation for 1986-87 growing season (data from AREC, Oma, FL).

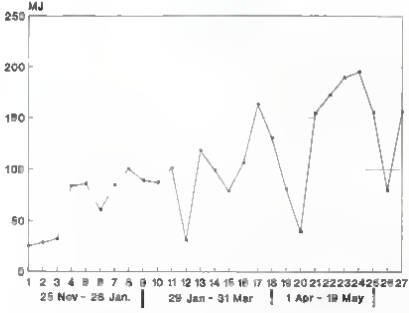


Fig. 2-8 Solar radiation for 1987-88 growing season (data from AREC, Ona, FL)

Analytical results from clay samples (taken prior to S1) shows P level to be very high with Ca Mg Zn Mn Cu and Fe being high and K moderate to low (Table 2-1)

In the early stage of both seasons there was an outbreak of powdery mildew in both crops, but the severity was higher and lasted longer in S1 Leaf spot (Helminthosporium Sativum Pam., King and Bakke) and leaf rust (Puccinia recondita tritici Desm.) was diagnosed in both seasons. In S1, the leaf spot was very severe and may have terminated kernal development, especially in the EP treatment

Birds were also a serious pest problem in the field. These observed included the red wing black bird (Aegelaius phoeniceus L.) the common grackle (Quiscalus quiscula L.), the boat tailed grackle (Quiscalus major Vieillot) and the mourning dove (Zenaida Macroura L.) These birds were present at both planting time and crop maturity. They did damage by scratching the kernels or pulling the young germinating seedlings from the soil, and by trampling the mature plant and removing the kernels from the spike. Kalmbacher et al. (1987) reported that they were unable to evaluate grain yields in one year's study due to bird damage. Knott and Gebeyehou (1987) also reported having problems with birds in their study

Time to Anthesis

The days to anthesis or vegetative period (VP) were longer for EP treatment compared to LP (Table 2-2) The VP for wheat EP was 9 days longer in S1 and 22 days longer in S2 while that of triticale was 1 day longer in S1 and 10 days longer in S2. The reduction of the VP for LP treatment was due to the onset of higher temperatures at a comparatively

Table 2-1 Organic matter (OM) pH and elements (by Mehlich I extractant) of phosphatic clay at Agrico site 1986-87

| | |
|---|---|
| pH | 7.2 |
| O.M. (%) | 2.0 |
| **Elements** | **(mg kg$^{-1}$)** |
| P | 1800.0 |
| K | 350.0 |
| Ca | 5060.0 |
| Mg | 1300.0 |
| Zn | 2.0 |
| Mn | 1.4 |
| Cu | 0.5 |
| Fe | 8.9 |

Means of 64 observations from 256 subsamples randomly taken over 4 plots each 12.2 x 5.5 square meters (Information from Dr. E. A. Hanlon and Mr. A. Jones Soil Science Department University of Florida Gainesville.)

Table 2-2 Timing of reproductive phase of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County

| Crop | Time of planting | Days to anthesis | | Days to harvest | |
|---|---|---|---|---|---|
| | | 1987 | 1988 | 1987 | 1988 |
| Wheat | EP | 108 | 104 | 160 | 143 |
| | LP | 99 | 82 | 139 | 123 |
| Triticale | EP | 87 | 89 | 160 | 143 |
| | LP | 86 | 75 | 139 | 123 |

EP = Early planting
LP = Late planting

earlier time in crop development Anthesis for wheat occurred around the 15th and 21st week of the growing season in S1 and 15th and 17th week of the growing season in S2 for EP and LP treatments, respectively, while triticale reached anthesis around the 12th and 19th week in S1 and the 13th and 16th week in S2 also for EP and LP treatments respectively

Since the EP treatments were seeded 6 to 7 weeks earlier than the LP treatment, they had the advantage of growing for a longer period at the lower seasonal temperatures The average temperatnre during most of the VP remained below 20°C for the EP treatment bnt rose above 20°C for rha LP treatment Higher temperatnres will accelerare plant development and therefore reduce the period of the growth stages (Evans and Wardlaw, 1976, Colville Baltenberger and Frey, 1987) Fischer (1985), in studying the influence of cooling and heating on wheat development found a reduction of up to 7 days in VP when the crop was subjected to heating Under the cooler temperatnres in North Florida (Lake City), Kanthali (1985) reported VP of up to 127 days for Florida 301 wheat

Treatment Effects

Combined ANOVA over both growing seasons (Table 2 3) showed a significant season effect ($p < 0.01$, 0 05) for grain yield (GYD) and yield componenrs such as kernal spike$^{-1}$ (KS) weight kernal$^{-1}$ (KW), weight spike$^{-1}$ (WPS) spike m$^{-2}$ (SPM) as well as test weight (TW) and harvest index (HI) There was a significant main effect (date) for both GYD and biomass (BYD) yield and yield components The subplot effect (crop) was significant for TW SPM KS, KW and WPS at $p < 0.01$ and for HI ar

Table 2-3. F test significance from combined ANOVA for yield, yield components, test weight, and harvest index of Florida 301 wheat and Florida 201 triticale (crops) at Agrico site Polk County over two growing seasons

| SOURCE | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spike $m^{-2}$ | Spike weight $m^{-2}$ | Weight spike$^{-1}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Rep (R) | 4 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Season (S) | 1 | * | NS | * | * | * | NS | * | * | * |
| R X \| S \| (Error) | 8 | | | | | | | | | |
| Date (D) | 1 | * | * | * | NS | * | * | * | § | * |
| S X D | 1 | * | § | § | * | * | * | NS | * | NS |
| R X D \| S \| (Error) | 8 | | | | | | | | | |
| Crop (C) | 1 | NS | NS | * | § | * | NS | * | * | * |
| S X C | 1 | NS | NS | * | NS | * | NS | NS | § | NS |
| D X C | 1 | NS | NS | § | NS | * | NS | § | * | § |
| S X D X C | 1 | NS | NS | * | NS | NS | NS | NS | § | § |
| D X R \| S \| X C (Error) | 16 | | | | | | | | | |
| CV | | 23 | 13 | 4 | 24 | 14 | 37 | 16 | 33 | 9 |

*,§ = Significant at $\alpha < 0.01$, 0.05 probability levels, respectively
NS = Not significant

$p < 0.05$. The season by date interaction was also significant for all the above variables except WPS and KW.

ANOVA for the individual years (seasons) are shown in Tables 2-4 and 2-5. In S1 there was a significant ($p < 0.01$) planting date effect for BYD, yield components TW and HI. Crop effect was significant for GYD ($p < 0.05$) and yield components ($p < 0.01$). The date by crop interaction was not significant for GYD or BYD but significant ($p < 0.01$) for TW, HI, SPM, and KS (Table 2-4). In S2 (Table 2-5), there was a significant date effect ($p < 0.01, 0.05$) for all variables. There was no effect of crops on GYD, BYD or HI. However, there was significant crop effect ($p < 0.01, 0.05$) for tiller height (TH), TW, and yield components except WPS and SPM. The date by crop interaction was significant ($p < 0.01$) for TW ($P < 0.05$) and for SPM and TH.

Grain Filling Duration and Dry Matter Accumulation

The early planted treatment (EP) had a longer EGFD than the late planted (LP) treatment for both wheat and triticale in both growing seasons (Tables 2-6 and 2-7). The EGFD was 13 days longer in S1 and 6 days longer in S2 for EP wheat and 11 days longer in S1 and 8 days longer in S2 for EP triticale relative to LP treatments. This reduction in the EGFD for LP treatments was the result of the higher temperatures at which they entered anthesis, and which was elevated for the remainder of the grain filling period. The average daily temperature at anthesis for LP treatments was 23°C vs 20°C for the EP treatments in both growing seasons (Figs. 2-5 and 2-6).

Table 2-4 F test significance from ANOVA for yield, yield components, test weight, and harvest index of Florida 301 wheat and Florida 201 triticale (crops) at Agrico site Polk County, 1986-87 growing season

| SOURCE | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spike $m^{-2}$ | Spike weight $m^{-2}$ | Weight spike$^{-1}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Rep (R) | 4 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Date (D) | 1 | NS | * | * | * | * | * | * | * | * |
| RXD (Error) | 4 | | | | | | | | | |
| Crop (C) | 1 | § | NS | * | § | * | NS | * | * | * |
| DXC | 1 | NS | NS | * | * | * | NS | NS | * | |
| RXC(D) (Error) | 8 | | | | | | | | | |
| CV | | 24 | 13 | 4 | 14 | 13 | 42 | 22 | 29 | 12 |

*,§ = Significant at or < 0.01, 0.05 probability levels respectively
NS = Not significant

Table 2-5 F test significance from ANOVA for yield, yield components test weight, harvest index and tiller height of Florida 301 wheat and Florida 201 triticale (crops) at Agricm site Polk County, 1987-88 growing season

| SOURCE | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spike $m^2$ | Spike weight $m^2$ | Weight spike$^{-1}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Tiller Height |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep (R) | 4 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Date (D) | 1 | * | * | * | § | * | * | * | * | * | * |
| RXD(Error) | 4 | | | | | | | | | | |
| Crop (C) | 1 | NS | NS | * | NS | * | § | * | * | * | * |
| DXC | 1 | NS | NS | * | NS | § | NS | NS | NS | NS | § |
| RXC¦D¦ (Error) | 8 | | | | | | | | | | |
| CV | | 22 | 13 | 1 | 25 | 18 | 26 | 13 | 19 | 2 | 37 |

* § = Significant at or < 0.01, 0.05 probability levels, respectively
NS = Not significant

Table 2-6. Grain development of early and late planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County, 1986-87 growing season

| Crop | Time of planting | Dry matter accumulation $m^{-2}$ $day^{-1}$ (g) | Dry matter accumulation kernel$^{-1}$ $day^{-1}$ (mg) | EGFD days |
|---|---|---|---|---|
| Wheat | EP | 3.03 | 1.08 | 33 |
| | LP | 5.11 | 1.04 | 20 |
| Triticale | EP | 4.84 | 0.96 | 41 |
| | LP | 3.01 | 0.63 | 30 |

EP = Early planting
LP = Late planting
EGFD = Effective grain filling duration

Table 2-7. Grain development of early and late planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County, 1987-88 growing season

| Crop | Time of planting | Dry matter accumulation $m^{-2}$ $day^{-1}$ (g) | Dry matter accumulation kernel$^{-1}$ $day^{-1}$ (mg) | EGFD days |
|---|---|---|---|---|
| Wheat | EP | 10.15 | 1.56 | 31 |
| | LP | 6.46 | 1.35 | 25 |
| Triticale | EP | 7.78 | 1.24 | 41 |
| | LP | 5.46 | 2.45 | 33 |

EP = Early planting
LP = Late planting
EGFD = Effective grain filling duration

This shortening of the EGFD due to elevation in temperatures is consistent with the results of previous research in both controlled studies (Sofield et al. 1977, Rasmusson et al., 1979, Warrington et al., 1977) and field conditions (Weigand and Cuellar 1981, Knott and Gebeyehou 1987, Nass and Reiser 1975, Brucknec and Frahberg 1987, Jones et al., 1979). Hunthall (1985) found that an increase in average daily temperature from 13°C to 27°C over the crop growing season in Lake City, FL, resulted in a 10 day reduction in the grain filling period of Florida 301 wheat. Sofield et al. (1977) reported that increasing temperature from 21/16°C to 35/25°C resulted in almost 50% reduction in grain growth duration.

Kernel (grain) DM accumulation of EP and LP treatments of both small grain crops over S1 and S2 are shown in Figs. 2-9 and 2-10. Growth rates, calculated over the linear phase of grain development, are given in Tables 2-6 and 2-7. On a unit area basis, DM accumulation rates of the EP treatment were lower for wheat in S1 but higher in S2, whereas it was higher for triticale in both seasons. On a per kernel level, the EP accumulation rates were slightly higher for wheat both in S1 and S2 and slightly higher for triticale in S1 but relatively lower in S2. It was expected that LP treatments would have had a higher growth rate. However, this difference was not realized here. Both treatments experienced similar temperatures for the greater part of the EGFD. Although EP treatments entered anthesis when average daily temp was about 20°C compared to about 23°C for LP treatments, both treatments completed the major portion of grain fill when the temperatures were 25°C or above (Figs. 2-5 and 2-6). The higher growth rates for EP treatments

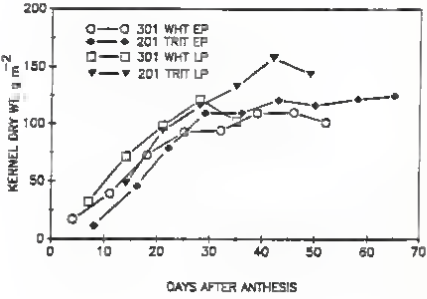


Fig. 4-9 Dry matter accumulation at early (EP) and late (LP) planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County, 1986-87 growing season.

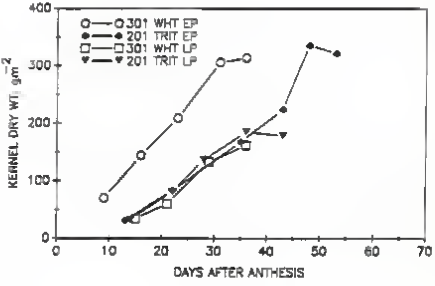


Fig 2-10 Dry matter accumulation of early (EP) and late (LP) planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County, 1987-88 growing season.

especially in S2 may also be associated with better moisture condition For example Cobeyehou et al (1982b) found that irrigation significantly increased grain filling rates in wheat

Regression equations fitted for DM accumulation of kernel and other growth parameters vs days after anthesis for both seasons are given in Tables 2 8 through 2-15 In S1, quadratic equations provided the best fit for the data Kernel dry matter accumulation was highly significant ($p < 0.01$ $r^2 = 0.53$ to 0 78) for both crops (Tables 2 8 through 2 11) However in S2 linear equations were best fitted to the kernel DM accumulation data ($p < 0.01$ 0 05 $r^2 = 0.40$ to 0 91) (Tables 2 12 through 2-15) This larger situation implies an abrupt growth termination under high temperatures This is similar to the experience of Sayed and Gadallah (1983) Growth rates of wheat was 1 08 and 1 04 mg kernel$^{-1}$ day$^{-1}$ in S1 and 1 58 and 1 35 mg kernal$^{-1}$ day$^{-1}$ in S2 for EP and LP treatments respectively Simultaneously growth rates of triticale were 0 96 and 0 63 mg kernal$^{-1}$ day$^{-1}$ in S1 and 1 24 and 2 45 mg kernel$^{-1}$ day$^{-1}$ in S2 Simmons (1987) stated that kernel growth is often in the range of 1 4 to 2 0 mg kernel$^{-1}$ day$^{-1}$ and that rates could vary depending on growth conditions

The pattern of kernel growth is sigmoidal with a lag phase shortly after anthesis followed by a linear phase (Evans and Wardlaw, 1976) The initial lag period may only be a few days in grain crops such as wheat although it maybe longer in others for example corn (Evans and Wardlaw, 1976) Under field conditions of increasing high temperatures, it is possible to miss this lag phase if samples are not taken at short intervals (e g 2-4 days) or to have abrupt growth termination If this

Table 2-8 Regression equations for dry matter accumulation of early planted Florida 301 wheat vs days after anthesis at Agrico site Polk County 1986-87 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernel weight $m^{-2}$ (g) | -5 2620 | 5 6184 | -0 0650 | 0 78* |
| 100 kernel weight (g) | 0 1053 | 0 1237 | -0 0014 | 0 91* |
| Spike weight $m^{-2}$ (g) | 279 0080 | 46 5985 | 0 6202 | 0 70* |
| Weight spike$^{-1}$ (g) | 0 3322 | 0 0532 | -0 0077 | 0 78* |

* = Model significant at $\alpha < 0.01$ probability level

Y estimate = $a + bt + b_1t_1^2$ where a = intercept b = slope and t = days after anthesis

Table 2-9 Regression equations for dry matter accumulation of early planted Florida 201 triticale vs days after anthesis at Agrico site Polk County 1986-87 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernel weight $m^{-2}$ (g) | -40 5198 | 8 0705 | 0 0771 | 0 53* |
| 100 kernel weight (g) | 0 9501 | 0 1917 | -0 0018 | 0 83* |
| Spike weight $m^{-2}$ (g) | 654 1276 | 14 6679 | ---- | 0 27§ |
| Weight spike$^{-1}$ (g) | 0 2577 | 0 1104 | 0 0011 | 0 84* |

*,§ = Model significant at $\alpha < 0.01$, 0.05 probability levels, respectively

Y estimate = $a + bt + b_1t_1^2$ where a = intercept, b = slope, and t = days after anthesis

Table 2-10 Regression equations for dry matter accumulation of late planted Florida 301 wheat vs. days after anthesis at Agrico site Polk County, 1986-87 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernel weight $m^{-2}$ (g) | -32.4743 | 10.5130 | -0.1817 | 0.89* |
| 100 kernel weight (g) | -0.6584 | 0.2237 | -0.0039 | 0.93* |
| Spike weight $m^{-2}$ (g) | 29.6962 | 34.6319 | -0.7207 | 0.34§ |
| Weight spike$^{-1}$ (g) | 0.0719 | 0.0697 | -0.0014 | 0.50* |

*,§ = Model significant at or < 0.01, 0.05 probability levels, respectively

Y estimate = $a + bt + b_1t_1^2$ where a = intercept, b = slope, and t = days after anthesis.

Table 2-11 Regression equations for dry matter accumulation of late planted Florida 201 triticale vs. days after anthesis at Agrico site Polk County, 1986-87 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernel weight $m^{-2}$ (g) | -0.6289 | 8.5143 | -0.1128 | 0.75* |
| 100 kernel weight (g) | 0.0310 | 0.1532 | -0.0020 | 0.83* |
| Spike weight $m^{-2}$ (g) | 255.7616 | 3.0742 | ---- | 0.26§ |
| Weight spike$^{-1}$ (g) | 0.7616 | 0.0887 | 0.0015 | 0.42* |

*,§ = Model significant at or < 0.01, 0.10 levels of probability, respectively

Y estimate = $a + bt + b_1t_1^2$ where a = intercept, b = slope, and t = days after anthesis

Table 2.12 Regression equations for dry matter accumulation of early planted Florida 301 wheat vs days after anthesis at Agrico site Polk County, 1987-88 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernel weight $m^2$ (g) | -29.5314 | 10.1543 | ---- | 0.91* |
| 100 kernel weight (g) | 1.2319 | 0.2181 | -0.0021 | 0.97* |
| Spike weight $m^2$ (g) | 138.8165 | 18.2453 | ---- | 0.66* |
| Weight spike$^{-1}$ (g) | 0.3031 | 0.0415 | ---- | 0.90* |

* = Model significant at or < 0.01 probability level

Y estimate = a + bt (linear model) or a + bt + $b_1t_1^2$ (quadratic model) where a = intercept, b = slope, and t = days after anthesis

Table 2.13 Regression equations for dry matter accumulation of early planted Florida 201 triticale vs days after anthesis at Agrico site Polk County, 1987-88 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | $R^2$ |
|---|---|---|---|
| Kernel weight $m^2$ (g) | -183.7581 | 7.7875 | 0.84* |
| 100 kernel weight (g) | 1.3323 | 0.1241 | 0.94* |
| Spike weight $m^2$ (g) | 68.2285 | 18.8683 | 0.70* |
| Weight spike$^{-1}$ (g) | -0.2845 | 0.0775 | 0.92* |

* = Model significant at or < 0.01 probability level

Y estimate = a + bt, where a = intercept, b = slope, and t = days after anthesis.

Table 2 14 Regression equations for dry matter accumulation of late planted Florida 301 wheat vs days after anthesis at Agrico site Polk County, 1987 88 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | $R^2$ |
|---|---|---|---|
| Kernal weight $m^{-2}$ (g) | -66 1505 | 6 4817 | 0 40§ |
| 100 kernel weight (g) | 1 2675 | 0 1359 | 0 93* |
| Spike weight $m^{-2}$ (g) | 24 2249 | 10 0110 | 0 59§ |
| Weight spike$^{-1}$ (g) | 0 0379 | 0 0321 | 0 80* |

*, § = Model significant at or < 0 01 0 05 probability levels respectively

Y estimate = a + bt where a = intercept b = slope and t = days after anthesis

Table 2 15 Regression equations for dry matter accumulation of late planted Florida 201 triticale vs days after anthesis at Agrico site Polk County, 1987 88 growing season

| Dependent variable (Y) | Coefficients: Intercept | Linear | Quadratic | $R^2$ |
|---|---|---|---|---|
| Kernal weight $m^{-2}$ (g) | -33 3394 | 5 4773 | ---- | 0 68* |
| 100 kernel weight (g) | 3 6063 | 0 3605 | -0 0038 | 0 97* |
| Spike weight $m^{-2}$ (g) | 25 2477 | 14 5248 | --- | 0 56§ |
| Weight spike$^{-1}$ (g) | 1 2411 | 0 1759 | 0 0019 | 0 74* |

*, § = Model significant at or < 0 01 0 05 probability levels, respectively

Y estimate = a + bt (linear model) or a + bt +$b_1t^2$ (quadratic model) where a = intercept, b = slope, and t = days after anthesis

happens the characteristic sigmoidal growth curve would not be realized We believe this is the case in this study (Figs 2-5 and 2-6), especially in S2 Seyed and Gadallah (1983) also reported deviation from the sigmoidal growth pattern, which they concluded was due to higher than normal field temperatures during the grain filling phase They reported temperature up to 33°C during grain filling period

The growth rates realized in this study are consistent with those of other researchers (Gebeyehou et al 1982a, Welgend and Cuellar, 1981) Sofield et al (1977) found ther growth rates in wheat kernel increased from 0 90 1 39 mg kernel day$^{-1}$ when the temperature was increased from 15/10°C to 30/25°C Increased growth rate is generally associated with a reduction in the duration of grain fill and consequently a reduction in GYD (Seyed and Gadallah 1983 Fischer 1985 Watdlew 1970)

The high positive and significant ($p < 0.01$) correlation between days from anthesis to senescence (period of grain fill) and kernel DM accumulation (Tables 2-16 through 2-23), supports previous reports arresting to the importance of a long grain filling duration Coefficients of correlation ranged from 0 70 to 0 80 and 0 83 to 0 90 for both EP and LP treatments in S1 and S2, respectively Gebeyehou et al (1982a) found highly significant ($p < 0.01$) and positive correlations between grain filling duration and yields in corn Daynard et al (1971), and Deynard and Kannenberg (1978) also found a positive relationship between grain yields and grain filling duration Also in corn, Coarke and Kennenberg (1989) found a positive but nonsignificant relationship between these two variables Knott and Gebeyehou (1987) reported inconsistent and small correlation between the variables while

Table 2-16 Correlation coefficients for grain dry matter accumulation of early planted Florida 301 wheat at Agrico site Polk County, 1986-87 growing season

| Treatment | Days after anthesis | Kernel weight $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1 0 | 0 8* | 0 87* | 0 67* | 0 71* |
| Kernel weight $m^{-2}$ | - | 1 0 | 0 95* | 0 88* | 0 83* |
| Weight kernel$^{-1}$ | - | - | 1 0 | 0 87* | 0 90* |
| Spike weight $m^{-2}$ | - | - | - | 1 0 | 0 95* |
| Weight spike$^{-1}$ | - | - | - | - | 1 0 |

* Significant at or < 0 01 probability

Table 2 17 Correlation coefficients for grain dry matter accumulation of early planted Florida 201 triticale at Agrico site Polk County, 1986 87 growing season

| Treatment | Days after anthesis | Kernel weight $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1 0 | 0 70* | 0 83* | 0 45* | 0 79* |
| Kernel weight $m^{-2}$ | - | 1 0 | 0 89* | 0 20 | 0 77* |
| Weight kernel$^{-1}$ | - | - | 1 0 | 0 49* | 0 89* |
| Spike weight $m^{-2}$ | - | - | - | 1 0 | 0 56* |
| Weight spike$^{-1}$ | - | - | - | - | 1 0 |

* Significant at or < 0 01 probability

Table 2-18 Correlation coefficients for grain dry matter accumulation of late planted Florida 301 wheat at Agrico site Polk County, 1986-87 growing season.

| Variables | Days after anthesis | Kernel weight $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.75* | 0.84* | 0.32 | 0.40§ |
| Kernel weight $m^{-2}$ | | 1.0 | 0.88* | 0.58* | 0.66* |
| Weight kernel$^{-1}$ | | | 1.0 | 0.42§ | 0.56* |
| Spike weight $m^{-2}$ | | | | 1.0 | 0.92* |
| Weight spike$^{-1}$ | | | | | 1.0 |

* = Significant at or < 0.01 probability
§ = Significant at 0.05 probability

Table 2-19 Correlation coefficients for grain dry matter accumulation of late planted Florida 201 triticale at Agrico site Polk County, 1986-87 growing season

| Variables | Days after anthesis | Kernel weight $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.77* | 0.84* | 0.38§ | 0.48* |
| Kernel weight $m^{-2}$ | | 1.0 | 0.91* | 0.16 | 0.31¶ |
| Weight kernel$^{-1}$ | | | 1.0 | 0.46* | 0.58* |
| Spike weight $m^{-2}$ | | | | 1.0 | 0.93* |
| Weight spike$^{-1}$ | | | | | 1.0 |

* = Significant at or < 0.01 probability
§ = Significant at 0.05 probability
¶ = Significant at 0.10 probability

Table 2-20. Correlation coefficients for grain dry matter accumulation of early planted Florida 301 wheat at Agrico site Polk County, 1987-88 growing season

| Variables | Days after anthesis | Kernel wt $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike wt $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.94* | 0.97* | 0.78* | 0.93* |
| Kernel weight $m^{-2}$ | - | 1.0 | 0.98* | 0.88* | 0.95* |
| Weight kernel$^{-1}$ | - | | 1.0 | 0.85* | 0.97* |
| Spike weight $m^{-2}$ | | | | 1.0 | 0.93* |
| Weight spike$^{-1}$ | | | | - | 1.0 |

* = Significant at or < 0.01 probability

Table 2-21. Correlation coefficients for grain dry matter accumulation of early planted Florida 201 triticale at Agrico site Polk County, 1987-88 growing season

| Variables | Days after anthesis | Kernel wt $m^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $m^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.79* | 0.95* | 0.70* | 0.91* |
| Kernel weight $m^{-2}$ | - | 1.0 | 0.87* | 0.83* | 0.82* |
| Weight kernel$^{-1}$ | - | | 1.0 | 0.76* | 0.96* |
| Spike weight $m^{-2}$ | | | | 1.0 | 0.81* |
| Weight spike$^{-1}$ | | | | | 1.0 |

* = Significant at or < 0.01 probability

Table 2-22. Correlation coefficients for grain dry matter accumulation of late planted Florida 301 wheat at Agrico site Polk County, 1987-88 growing season

| Variables | Days after anthesis | Kernel weight $g^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $g^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.63* | 0.95* | 0.76* | 0.86* |
| Kernel weight $g^{-2}$ | - | 1.0 | 0.58* | 0.63* | 0.49§ |
| Weight kernel$^{-1}$ | - | - | 1.0 | 0.72* | 0.90* |
| Spike weight $g^{-2}$ | - | - | - | 1.0 | 0.66* |
| Weight spike$^{-1}$ | - | - | - | - | 1.0 |

* = Significant at or < 0.01 probability
§ = Significant at 0.05 probability

Table 2-23. Correlation coefficients for grain dry matter accumulation of late planted Florida 201 triticale at Agrico site Polk County, 1987-88 growing season

| Variables | Days after anthesis | Kernel weight $g^{-2}$ | Weight kernel$^{-1}$ | Weight spike$^{-1}$ | Spike weight $g^{-2}$ |
|---|---|---|---|---|---|
| Days after anthesis | 1.0 | 0.91* | 0.96* | 0.83* | 0.95* |
| Kernel weight $g^{-2}$ | - | 1.0 | 0.96* | 0.88* | 0.91* |
| Weight kernel$^{-1}$ | - | - | 1.0 | 0.81* | 0.93* |
| Spike weight $g^{-2}$ | - | - | - | 1.0 | 0.92* |
| Weight spike$^{-1}$ | - | - | - | - | 1.0 |

* = Significant at or < 0.01 probability

Munthali (1985) found a positive correlation in one location but negative in another. Other studies however have found distinct negative correlation between the two factors (Bruckner and Frohberg, 1987b; Metzger et al., 1984; Hess and Kelser, 1975; Wych et al., 1984; Herrera et al., 1989; Sayed and Ghanderah, 1984). These contrasting reports suggest that the level of correlation or noncorrelation tend to be environment or condition specific and probably should be studied on that basis.

Response Variables

Average GYD, SYD, TW, and HI for planting date (main effects) are shown in Tables 2.24 and 2.25. Both crops had higher SYD at the EP date and higher HI at the LP date in S1 (1986-87 season). Early planted triticale also had higher TW. However, in S2 (1987-88 season) all response variables except HI were significantly different and higher for EP treatment compared to LP treatment of both crops.

It was expected that the EP treatment would give higher yields compared to LP treatment. However, this was not the case in S1. High disease incidence may have adversely affected S1 results. Evans and Wardlaw (1976), Simmons (1987), and McCloud (1982) stated that pre- and post-anthesis events, such as achieving optimum leaf area and maintaining a good crop canopy, are important for grain yields. The flag leaf and spike are responsible for approximately 70% of the post-anthesis photosynthate going to the kernel, while up to 27% may come from pre-anthesis reserves. Consequently, if the crop canopy is damaged, assimilation and partitioning of photosynthate will be impaired. Diseased

Table 2-24 Yield response of Florida 301 wheat to planting date at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | | |
|---|---|---|---|---|---|---|
| Variables | Early | | Late | Early | | Late |
| Grain yield (kg ha$^{-1}$) | 1010 | | 1020 | 3130 | * | 1620 |
| Test weight (kg hl$^{-1}$) | 62 | | 62 | 80 | * | 75 |
| Biomass yield (kg ha$^{-1}$) | 8090 | * | 4610 | 8430 | * | 5500 |
| Harvest index (%) | 12 5 | * | 22 1 | 37 1 | | 29 4 |

* = Means within season are not significantly different LSD = 0 05

Table 2-25 Yield response of Florida 201 triticale to planting date at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | | |
|---|---|---|---|---|---|---|
| Variables | Early | | Late | Early | | Late |
| Grain yield (kg ha$^{-1}$) | 1240 | | 1430 | 3210 | * | 1800 |
| Test weight (kg hl$^{-1}$) | 62 | * | 53 | 69 | * | 66 |
| Biomass yield (kg ha$^{-1}$) | 9130 | * | 4290 | 8000 | * | 5590 |
| Harvest index (%) | 13 5 | * | 33 4 | 40 1 | | 32 2 |

* = Means within season are not significantly different LSD = 0 05

conditions may cause premature senescence resulting in shriveled kernels with low TW due to improper grain fill

Response to planting date in S2 is more consistent with those reported in the literature (Francis et al., 1984; Knapp and Knapp, 1978; Thill et al., 1978; Pitman and Andrews, 1960; Stickler and Pauli, 1961; Asana and Williams, 1965). Early planting generally gives higher yields whereas late planting tends to reduce yields. Planting too early may also cause low yields if the conditions are too cold (Paulsen, 1987). At Ona, Kalmbacher et al. (1987) found that both grain and forage yields were reduced with late-planted small grains. Black and Siddoway (1977) in Montana found that seeding winter wheat late or early resulted in yield reduction in both grain and straw (biomass). They reported grain yield loss of 60 and 40% in one location. Colville and Frey (1986), and Colville, Baltensperger and Frey (1987) found that delay in planting date also reduced grain and straw yields and yield components in oat. Cihacek (1983) reported consistent yield reduction of late planted small grain crops over a three year period. Rochefort et al. (1988) also reported significant yield decrease for late planted compared to early planted wheat.

The crops are compared in Tables 2-25 and 2-27. At the LP date in S1, GYD of triticale was higher than wheat GYD but TW of EP wheat was higher. LP triticale also had higher HI than wheat (Table 2-26). In S2 the only difference between the crops was the higher TW for wheat at both planting dates (Table 2-27).

The grain and biomass yields reported here on a per crop basis are similar to those reported by Kalmbacher et al. (1987), Mielavy et al.

Table 2.26 Comparative yields of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County 1986-87 growing season

| | Early planting | | Late planting | | |
|---|---|---|---|---|---|
| Variables | Wheat | Triticale | Wheat | | Triticale |
| Grain yield (kg ha$^{-1}$) | 1010 | 1240 | 1020 | * | 1430 |
| Test weight (kg hl$^{-1}$) | 62 | 62 | 62 | * | 53 |
| Biomass yield (kg ha$^{-1}$) | 8090 | 9130 | 4610 | | 4290 |
| Harvest index (%) | 12 5 | 13 5 | 22 1 | * | 33 4 |

* = Means within planting date are not significantly different LSD = 0 05

Table 2.27 Comparative yields of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County 1987-88 growing season

| | Early planting | | Late planting | | |
|---|---|---|---|---|---|
| Variable | Wheat | Triticale | Wheat | | Triticale |
| Grain yield (kg ha$^{-1}$) | 3130 | 3210 | 1620 | | 1800 |
| Test weight (kg hl$^{-1}$) | 80 | * 69 | 75 | * | 66 |
| Biomass yield (kg ha$^{-1}$) | 8430 | 8000 | 5500 | | 5590 |
| Harvest index (%) | 37 1 | 40 1 | 29 4 | | 32.2 |

* = Means within planting date are not significantly different LSD = 0 05

(1984) Muntholi (1985) Calhoun (1988) the 1987 IFAS agronomy research report (Anonymous 1987), and Barnett and Luke (1979) The comparative yields in S2 are also similar to the findings of Morey (1979) who compared wheat with triticale

An important finding of this research is the relationship between GYD and BYD (Tables 2-28 through 2-30) (BYD includes the grain component plus all other aerial plant parts) The highly significant ($p < 0.01$) and positive ($r^2 = 0.42$) correlation found between the two variables over both seasons, and in S2 ($r^2 = 0.82$) (Tables 2-28 and 2-30) indicates that the extent of morphological development in the VP strongly influences the outcome of grain yields Perhaps research emphasis should be directed in this area, i e , to study the relationship of the product or products of the vegetative period with grain yield This may help to clarify the inconsistency seen in the literature regarding the correlation/noncorrelation of the VP with final grain yield Gebeyehou et al (1982b) reported a simple correlation between grain yield and VP but also stated that the correlation between kernel weight and VP was highly significant Wych et al (1982) found a positive correlation between grain yield and days to heading in one season and a negative correlation the next season Nass and Kaiser (1975) also reported negative correlation between days to anthesis and grain yield Munthali (1985) found a small negative nonsignificant correlation in one year and a moderately positive but nonsignificant correlation the following year between these same two variables Knott and Gebeyehou (1987) also reported positive relationship between kernel weight and vegetative period

Table 2-28. Overall correlation coefficients for grain yield and yield components of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County over 1986-87 and 1987-88 growing seasons.

| Parameter | Grain yield | Biomass yield | Spike $m^{-2}$ | Spike no. $m^{-2}$ | Weight spike$^{-1}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test wt. | Harvest Index | Tiller height |
|---|---|---|---|---|---|---|---|---|---|---|
| Grain yield | 1.0 | 0.42* | -0.21 | 0.05 | 0.43* | 0.58* | 0.63* | 0.58* | 0.80* | 0.63* |
| Biomass yield | | 1.0 | 0.35§ | 0.70* | 0.36§ | 0.23 | 0.35§ | 0.31§ | -0.16 | 0.58* |
| Spike $m^{-2}$ | - | - | 1.0 | 0.34§ | -0.46* | 0.66* | 0.54* | 0.03 | 0.47* | 0.58* |
| Spike weight $m^{-2}$ | | - | | 1.0 | 0.46* | -0.42* | 0.21 | 0.04 | 0.33§ | 0.78* |
| Weight spike$^{-1}$ | | | | | 1.0 | 0.32§ | 0.83* | -0.03 | -0.27¶ | 0.79* |
| Kernel spike$^{-1}$ | | - | | - | | 1.0 | 0.47* | 0.01 | 0.80* | 0.57* |
| Weight kernel$^{-1}$ | | - | | - | | | 1.0 | 0.40* | 0.47* | 0.79* |
| Test weight | | | | | | | | 1.0 | 0.35§ | 0.26 |
| Harvest Index | | | | | | | | | 1.0 | 0.40¶ |
| Tiller height | | | - | | | | | | | 1.0 |

* = Significant at or < 0.01 probability
§ = Significant at or < 0.05 probability
¶ = Significant at or < 0.10 probability

Table 2-29. Overall correlation coefficients for yield and yield components of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County 1986-87 growing season

| | Grain | Biomass | Spike $m^{-2}$ | Spike $m^{-2}$ | Weight | Kernel $spike^{-1}$ | Weight $spike^{-1}$ | Test | Harvest |
|---|---|---|---|---|---|---|---|---|---|
| Grain yield | 1 0 | 0 03 | 0 47§ | 0 31 | 0 24 | 0 64* | 0 45§ | -0 22 | 0 59* |
| Biomass yield | - | 1 0 | 0 41§ | 0 76* | 0 4* | 0 57* | 0 57* | 0 47 | 0 77* |
| Spike $m^{-2}$ | - | - | 1 0 | 0 29 | 0 41¶ | 0 70* | 0 39¶ | -0 62* | -0 66* |
| Spike weight $m^{-2}$ | - | - | - | 1 0 | 0 56* | 0 56* | 0 49§ | 0 29 | 0 72* |
| Weight $spike^{-1}$ | - | - | - | - | 1 0 | 0 03 | 0 86* | 0 17 | 0 14 |
| Kernel $spike^{-1}$ | - | - | - | - | - | 1 0 | 0 16 | -0 77* | 0 90* |
| Weight $kernel^{-1}$ | - | - | - | - | - | - | 1 0 | 0 06 | 0 19 |
| Test weight | - | - | - | - | - | - | - | 1 0 | 0 64* |
| Harvest Index | - | - | - | - | - | - | - | - | 1 0 |

* = Significant at or < 0 01 probability
§ = Significant at 0 05 probability
¶ = Significant at 0 10 probability

Table 2-30 Overall correlation coefficients for yield and yield components of Florida 301 wheat and Florida 201 triticale at Agrico site Polk County 1987 88 growing season

| Variables | Grain yield | Biomass yield | Spike $m^{-2}$ | Spike $m^{-2}$ | Weight spike$^{-1}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test wt | Harvest index | Tiller height |
|---|---|---|---|---|---|---|---|---|---|---|
| Grain yield | 1 0 | 0 82* | 0 51§ | 0 76* | 0 37 | 0 65* | 0 32 | 0 21 | 0 77* | |
| Biomass yield | | 1 0 | 0 41¶ | 0 76* | 0 43§ | 0 57* | 0 57* | 0 51 | 0 77* | |
| Spike $m^{-2}$ | | - | 1 0 | 0 29 | 0 41¶ | 0 70* | 0 39¶ | 0 62* | 0 66* | |
| Spike weight $m^{-2}$ | | - | | 1 0 | 0 56* | 0 58* | 0 49§ | 0 29 | 0 72* | |
| Weight spike$^{-1}$ | | | | | 1 0 | 0 03 | 0 86 | -0 17 | | 0 16 |
| Kernel spike$^{-1}$ | | | | | | 1 0 | 0 16 | | 0 77* | 0 90* |
| Weight kernel$^{-1}$ | | | | | | | 1 0 | 0 27 | 0 08 | -0 19 |
| Test weight | - | - | | | | | | 1 0 | 0 64* | |
| Harvest index | - | | | | | | | | 1 0 | |
| Tiller height | | | | | | | | | | 1 0 |

* = Significant at or < 0 01 probability
§ = Significant at 0 05 probability
¶ = Significant at 0 10 probability

Since pre-anthesis development will affect final grain yields (Evans and Wardlaw 1976), it follows that the extent of the developmental phases should affect yield outcome. Dunphy et al (1984) found a concomitant decrease in grain yield with leaf area index (LAI) and that grain yield was positively correlated with LAI at anthesis in small grains. Root development ceases with the onset of the reproductive phase (Asana and Williams, 1975; Evans and Wardlaw, 1976). Therefore, the extent of their development at that stage will affect their nutrient harvesting ability and, consequently, their contribution to above ground plant development. Comfort et al (1955) cited Grabonski (1976) as suggesting that wheat crops with deeper penetrating roots were better able to reach subsoil N during grain filling. Bruckner and Frohberg (1987a) also cited Geyerhern (1977) as reported a positive relationship between spring wheat yields and plant available water in the root zone. Tiller development in terms of numbers and height all of which takes place prior to anthesis (Rocheford et al., 1985), will also affect final yields. Gebeyehou et al (1982b) found that a long vegetative period duration positively affected grain yield through its effect on yield components. The correlation found in this study was similar to that of Winter and Thompson (1967) who reported positive and significant correlation (r = 0.90) between grain yield and biomass.

Test weight is a function of the packing volume and density of the kernel. This may be affected by wrinkled, broken, damaged or unfilled kernels due to environmental conditions (Yamazaki and Briggle, 1969). The climatic conditions at Agrico during the period of the research may have influenced the TW of EF vs. LP treatments for the crops (Tables 2-24

through 2-27) although there was no difference for wheat in S1 (Table 2-24). Gihe (1983) also reported lower TW with later planting date for small grains. The higher TW for wheat compared to triticale (Tables 2-26 and 2-27) is similar to the findings of Barnett and Luke (1978) and Morey (1978) who found that wheat had higher TW when the two crops were compared. Harvest index serves as a measure of the carbohydrate which goes into grain (Simmons 1987). Planting date effected HI in S1 but not in S2 (Tables 2-24 through 2-27). This may be attributed to growing conditions. A similar pattern of alternating effects of planting date on HI in oat have been reported by Colville and Frey (1986) and Colville Baltenberger and Frey (1987).

Yield Components

The main components of grain yield in small grain crops such as wheat are spike $m^{-2}$ (plant density), kernel spike$^{-1}$, and weight kernel$^{-1}$ (size). Final grain yield is a function of these components which depending on environmental conditions can behave in a compensatory manner (Evans and Wardlaw, 1976). Biomass yield (above ground), on the other hand, is comprised of all aerial plant parts. Individual and comparative yield components for the two crops are given in Tables 2-31 through 2-34. The EP wheat had more spike $m^{-2}$ compared to the LP in S1. In S2 the EP treatment was higher for all the major components except KS (Table 2-31). The EP triticale was higher for all main components in S1 and all except SPM in S2 (Table 2-31). Both crops had taller tillers for the EP treatment in S2. Thill et al. (1978) also reported more SPM (heads) for early planted compared to late planted wheat.

Table 2-31 Yield components of Florida 301 wheat at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | | |
|---|---|---|---|---|---|---|
| Components | Early | | Late | Early | | Late |
| Spike $m^2$ | 860 | * | 484 | 450 | * | 310 |
| Spike weight $m^2$ (g) | 1080 | * | 370 | 745 | * | 368 |
| Weight spike$^{-1}$ (g) | 1 30 | * | 0 80 | 1 70 | * | 1 80 |
| Kernel spike$^{-1}$ | 5 00 | | 9 00 | 19 00 | | 14 30 |
| Weight kernel$^{-1}$ (mg) | 24 70 | | 23 00 | 38 60 | * | 34 00 |
| Tiller height (cm) | --- | | --- | 38 00 | * | 29 00 |

* = Means within season are not significantly different LSD = 0 05

Table 2-32 Yield components of Florida 201 triticale at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | |
|---|---|---|---|---|---|
| Components | Early | | Late | Early | Late |
| Spike $m^2$ | 367 | * | 178 | 242 | 213 |
| Spike weight $m^2$ (g) | 1377 | | 344 | 903 | 584 |
| Weight spike$^{-1}$ (g) | 2 90 | | 1 90 | 3 70 | 2 70 |
| Kernel spike$^{-1}$ | 7 50 | | 29 20 | 26 50 | 18 60 |
| Weight kernel$^{-1}$ (mg) | 39 80 | | 28 60 | 51 40 | 47 00 |
| Tiller height (cm) | --- | | --- | 43 | 37 |

* = Means within season are not significantly different LSD = 0 05

Table 2-33 Comparative yield components of early planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | | |
|---|---|---|---|---|---|---|
| Components | Wheat | | Triticale | Wheat | | Triticale |
| Spike $m^{-2}$ | 860 | * | 367 | 450 | * | 242 |
| Spike weight $m^{-2}$ (g) | 1080 | | 1377 | 745 | | 903 |
| Weight spike$^{-1}$ (g) | 1 30 | * | 2 90 | 1 70 | * | 3 70 |
| Kernel spike$^{-1}$ | 5 00 | * | 29 20 | 19 00 | * | 26 50 |
| Weight kernel$^{-1}$ (mg) | 24 70 | * | 39 80 | 38 60 | * | 51 40 |
| Tiller height (cm) | --- | | --- | 38 | * | 43 |

* = Means within season are not significantly different LSD = 0 05

Table 2-34 Comparative yield components of late planted Florida 301 wheat and Florida 201 triticale at Agrico site Polk County over two growing seasons

| | 1986-87 Season | | | 1987-88 Season | | |
|---|---|---|---|---|---|---|
| Components | Wheat | | Triticale | Wheat | | Triticale |
| Spike $m^{-2}$ | 484 | * | 178 | 310 | * | 213 |
| Spike weight $m^{-2}$ (g) | 370 | | 344 | 368 | | 584 |
| Weight spike$^{-1}$ (g) | 0 80 | * | 1 90 | 1 20 | * | 2 70 |
| Kernel spike$^{-1}$ | 9 00 | | 7 50 | 14 00 | * | 18 60 |
| Weight kernel$^{-1}$ (mg) | 23 00 | | 28 60 | 34 50 | * | 47 00 |
| Tiller height (cm) | --- | | --- | 29 | * | 37 |

* = Means within season are not significantly different LSD = 0 05

Comparison of the crops for EP treatments showed higher SPM for wheat but KS and KW were higher for triticale in S1 in S2 triticale had higher KW and KS but wheat had higher SPM (Table 2-33). The LP treatments (Table 2-34) showed a higher SPM for wheat in S1 and S2 but triticale had higher KW. Triticale also had taller tillers. Final grain yield was negatively correlated with SPM for both crops in S1 (Table 2-29) and positively correlated with SPM and KS in S2 (Table 2-30). As shown in Tables 2-28 through 2-30 there was inconsistent correlation/noncorrelation among the major components. This type of sensitive relationship has been discussed by Evans and Wardlaw (1976)

## Summary and Conclusions

Agricultural reclamation of phosphatic clay areas in Polk County, Florida, will be beneficial to both the county and the state. Small grains could play a positive role in the reclamation program. A study was conducted over a two year period to evaluate the effects of the environment on the yield potential of Florida 301 wheat and Florida 201 triticale. Climatic conditions, pests and disease incidence may have adversely influenced results in the first year but less so in the second year. Planting the crops early gave better results. Late planting subjected the crop to higher temperatures during the development and reproductive period. Delayed planting reduced grain filling duration by an average of 9.5 days over the two seasons. Grain and biomass yields for the late planting were reduced by approximately 50% compared to the early planting in the second year.

There was little or no difference between the crops in terms of grain and biomass yields Also both the grain and biomass yields for the crops are consistent with data from other studies Although the climatic conditions were not optimal for small grains in this section of the state the high fertility of the clays coupled with good management practices should make it possible to produce these crops in the environment

The high, positive and significant correlations found between grain and biomass yields suggests that developments during the vegetative phase may strongly impact upon final grain yields Further research should be carried out in this area for proper documentation

CHAPTER 3
YIELDS AND GRAIN QUALITY OF TWO SMALL GRAIN CROPS IN RESPONSE TO NITROGEN FERTILIZER ON PHOSPHATIC CLAYS

## Introduction

The main purpose of reclaiming mined out land areas is to restore the productive capacity equal to or better than it was prior to mining. Mined or reconstructed soils often have unique properties (chemical and physical), thereby rendering them different from natural soils. Utilization of mined soils for crop production requires an understanding between the crop, the environment, and management factors such as fertilizer application, moisture requirement, plant population, etc. Preliminary investigations have indicated that mined out phosphatic clay areas in Polk County, South Central Florida, have very good crop production capacity and should therefore easily lend itself to agricultural reclamation. In fact, at a field day held on 27 April 1959 to demonstrate this attribute, Dr. C. M. Prine, a crop ecologist at the University of Florida, IFAS, stated that "we have not found a plant that would not grow here" (Neary, 1989). Nitrogen may be the only limiting major element to crop production in this environment since the clays contain moderate to high quantities of all the others (Hochmuth et al., 1987; Mislevy et al., 1989). Mislevy et al. (1989) reported that N was the only element needed to produce up to 13.9 6 Mg $ha^{-1}$ $yr^{-1}$ of perennial grass on these clays. Also from recent studies (data unpublished) in the

same environment. Jones (1989) and Hochmuth et al (1989) stated that up to 168 kg ha$^{-1}$ of N was required for good production of both rice (Oryza sativa L.) and cole crops.

Fertilizer management is imperative for good yields in small grain crops. Among the major nutrients, N is required in the largest quantities and is considered as the "key" element in the production of these crops (Wright and Barnett, 1985). However, this requirement will vary depending on environmental conditions. In North Florida, for example, the recommended N rates range from 33.6 to 89.6 kg ha$^{-1}$ depending on whether the crop is planted early or late. It is also suggested that application in excess of these rates do not result in higher yields (Wright and Barnett, 1985, 1986; Wright et al., 1985; Wright et al., 1983, Calhoun and Barnett, 1986). In Georgia, the recommendation range for wheat (Triticum aestivum em. Thell) is between 67.2 to 134 kg ha$^{-1}$ of N depending on whether the crop follows soybeans (Glycine max L.) peanuts (Arachis hypogaea L.) or sorghum (Sorghum bicolor L.) (Segars, 1986). Eck (1988) applied N from 0 to 210 kg ha$^{-1}$ to winter wheat grown under dry land conditions on a clay loam soil. He reported that 140 kg ha$^{-1}$ of N was adequate for maximum grain yield in one situation while 70 kg ha$^{-1}$ was adequate in another. Bruckner and Morey (1988) also studied N effects on wheat yields on a clay loam soil. They reported that biomass and grain yields were maximized at 106 and 94 kg ha$^{-1}$, respectively. Roth et al. (1984) reported best grain yields for soft red winter wheat of over 4000 kg ha$^{-1}$ when 34 kg ha$^{-1}$ of N was applied. In their study on forage production, Comfort et al. (1988) reported higher biomass yields when 67 kg ha$^{-1}$ of N were applied. Halvorson et al. (1987) stated that the

quantity of N required to optimize yields of a complete wheat crop ranged from 30 to 50 kg of N per Mg of grain produced depending on geographical location. Ruder (1985) stated that 70 kg ha$^{-1}$ of N is required to produce 3 Mg of wheat grain plus 3.5 Mg of straw.

While high levels of N are required for good yields, excessive amounts can adversely affect both yields and grain quality. Bruckner and Morey (1988) found that N application in excess of 105 kg ha$^{-1}$ depressed both grain and biomass yields while protein content increased with additional N between 34 to 134 kg ha$^{-1}$. Fowler et al. (1989) reported that grain yield depression at high N rates was a physiological response. Lodging may also result from excessive N rates as reported by Roth et al. (1984). N utilization by small grains tends to plateau at an optimum range but, as previously mentioned, this range seems to differ with the environment.

Small grain crop varieties have been recently developed at the North Florida Research and Education Center (NFREC) - Quincy (Barnett and Luke, 1980; Calhoun and Barnett, 1986), which shows a greater tolerance for more hot and humid conditions such as exist in South Florida.

Two of these crops, Florida 301 wheat and Florida 201 triticale (X Triticosecale Wittmack), the latter a man-made intergeneric hybrid which combines the yield potential and quality of wheat with the hardiness of rye (Secale cereale L.) (Morey, 1979; Barnett and Luke, 1979; Zillinsky, 1985), were selected for testing by the Mined Lands Research/Demonstration project.

Production of these crops on phosphatic clays in Florida is a new endeavor. Consequently, there are no available data documenting their N

requirements in this type of environment. Therefore, the objectives of this study were to (1) determine the optimum N requirement for economic production of the crops, and (2) evaluate the N effects on the quality of the grain produced on phosphatic clays.

## Materials and Methods

Field studies were conducted at the Agrico site of the Mined Lands Research/Demonstration Project in Polk County, Florida. The site is located approximately 34 km southwest of the town of Bartow. Geographical location of Bartow is latitude 27°54' N and longitude 81°51' W. Elevation is 36.7 meters above sea level. Average annual precipitation is 431.8 mm and average midnight temperature is 17°C (National Oceanic and Atmospheric Administration, 1987-88). The research area was part of a 200 hectare recently reclaimed phosphatic clay settling pond. Clay samples were taken over the general area for elemental analysis.

Florida 301 wheat (a winter/facultative) and Florida 201 (a spring type) triticale were grown on the site over the 1986-87 (S1) and 1987-88 (S2) growing seasons. Before S1 planting, the area was cropped to alfalfa (*Medicago sativa* L.). The S2 small grain crop was preceded by an unfertilized crop of tropical corn (*Zea mays* L.). In both seasons the land was disked and power tilled twice to break up clods. In S2 this was followed by a mellowing period. Mellowing is a process whereby alternate wetting and drying causes the large clay aggregates (clods) to shrink and crumble into smaller size particles. This allows for a more uniform seedbed.

The two small grain crops were grown at five N levels of 0, 56, 112, 168 and 224 kg ha$^{-1}$. A split plot experimental design was used. Nitrogen levels were main plot and crop was subplot. The treatment combinations were replicated five times. Planting was on the 21 November 1986 in S1 and 10 December 1987 in S2. The later S2 plantings were due to inclement weather which prevented November planting as in S1. The recommended time for planting small grains in North Florida is 15 November to 15 December for wheat, and 25 November to 1 January for triticale (Calhoun and Barnett, 1986; Barnett and Wright, 1986). Each plot had seven rows, each 6.10 m with and 17.5 cm between rows. A grain drill equipped with double disk openers was used for planting. Planting rates were 90 kg ha$^{-1}$ for wheat and 112 kg ha$^{-1}$ for triticale.

Management Practices

Nitrogen was supplied by $NH_4NO_3$ and was applied at early tillering (stage 2-4, Large, 1954). Plots were also fertilized with 112 kg ha$^{-1}$ of $K_2SO_4$ (to give 50 kg of K and 20 kg of S per hectare). Overhead sprinkle irrigation was applied in the early stages to facilitate seedling emergence and stand establishment. Plots were sprayed with Bavistin (benomyl) and sevin (carbaryl) both at 1.12 kg ha$^{-1}$ in S1 and with Dithane M45 (mancozeb) at 2.24 kg ha$^{-1}$, and Lannate (methomyl) at 0.95 liter ha$^{-1}$ in S2 to control powdery mildew (Erysiphe graminis DC.) and aphids (Schizaphis graminum Rond.). Weed control was carried out manually as necessary.

Data Collection and Analysis

Climatological data (measured in the township of Bartow) on temperature and precipitation for the experimental period were extracted from publications of the National Oceanic and Atmospheric Administration (NOAA). Solar radiation data were from the AREC at Ona located approximately 42 km southwest of the research site.

In both seasons, data were collected on biomass yield, grain yield, and yield components. In S2 tiller height at anthesis was also measured. Because a high incidence of lodging was observed in the plots in S1 (especially in the wheat), the plots were rated for lodging.

Final harvests were carried out on 30 April in S1 and 28 April in S2. The central 3.09 and 4.64 m of the five inner rows from each plot were harvested in S1 and S2, respectively. A mower equipped with a sickle bar was used for harvesting. Plants were cut to a stubble height of approximately 7 to 10 cm. Prior to harvest, spikes were randomly counted from three one-m row section of each plot to determine spikes $m^{-2}$ (SPM). Harvested samples were collected and dried in a grain dryer for five days, weighed for biomass, and then threshed with a Vogel thresher. Grains were then collected, cleaned, and weighed for yield determination.

Grain samples from four replications were sent to Woodson-Tenant Laboratories, Inc., of Des Moines, IA for proximate analysis (determination of protein fibre, moisture, fat, and ash) and phosphorous content. Percent protein was calculated using the Millers factor which is = N X 5.7

Analysis of variance, mean seperation, and regression analysis was carried out where appropriate (Petersen, 1977; Gomez and Gomez, 1984) using the SAS PC programs (SAS Software, 1988).

Economic analysis was carried out on the mean grain yield response to applied N calculated as

$$NI = TI - TC$$

where NI = net income

TI = total income

TC = total cost

For wheat and triticale, production costs consist of nitrogen purchases and other costs such as tillage operation, pesticides, labor, harvesting, etc. Therefore

$$TC = X(Px) + \text{other costs}$$

where X = total units of nitrogen

Px = unit price of nitrogen

and $NI = GYD(Pg) - X(Px) - \text{other costs}$

where GYD = total grain yield

Pg = unit price of grain

and $TI = GYD(Pg)$

Since the interest is in the economic value of N on the production of wheat and triticale, all other costs are assumed to be the same and only N is being varied. Essentially, net income will be maximized where N is applied in quantities such that the marginal value of N in production of the crops is equal to the marginal costs of N. (The above is an adaptation from the models of Hildebrand and Poey, 1985, and Taylor et al., 1955.)

## Results and Discussion

### Growing Conditions

Results of climatological data, incidence of disease and pest infestation, and analysis of clay samples (taken prior to S1) in this study are the same as reported in Chapter 2

### Interactions and Treatment Effects

Combined ANOVA for the growing seasons (Table 3.1) showed a highly significant seasons X N interaction ($P < 0.001$) for grain yield (GYD), biomass yield (BYD), kernel weight (KW). Season X N interaction for test weight (TW), spike $m^{-2}$ (SPM), and harvest index (HI) was also significant at $P < 0.01$, 0.05 and 0.10, respectively. The season X crop interaction was significant $P < 0.001$ for TW and SPM, and at $P < 0.01$ for KW. The S X N X C interaction was significant at $P < 0.05$ for GYD only. Due to these interactions, the data was further analyzed on the basis of individual seasons.

Tables 3-2 and 3-3 show the ANOVA for S1 and S2 respectively. The N X C interaction was not significant for any of the parameters measured in S1, but the main effect (N) was significant ($P < 0.05$) for BYD and KW and at $P < 0.01$ for TW. Subplot effect (C) was significant at $P < 0.05$ for GYD and HI, at $P < 0.10$ for BYD and TW and at $P < 0.001$ for SPM, KS, and KW (Table 3-2). In S2 (Table 3-3) the N X C interaction was significant at $P < 0.05$ for GYD and highly significant ($P < 0.001$) for TW and KW. The nitrogen effect was highly significant ($P < 0.001$) for GYD, BYD, TW, and KW, and at $P < 0.01$ for SPM, KS and tiller height (TH). The

Table 3-1 F test significance from combined ANOVA for yield and yield parameters of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County over two growing seasons.

| Source | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spikes $m^{-2}$ | Kernels spike$^{-1}$ | Weight kernel$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| Season (S) | 1 | * | § | * | * | § | * | * |
| Rep (S) (Error) | 8 | - | - | - | - | - | - | - |
| Nitrogen (N) | 4 | * | * | § | ¶ | NS | ¶ | NS |
| SXN | 4 | * | * | § | # | ¶ | § | * |
| Rep X N (S) (Error) | 32 | - | - | - | - | - | - | - |
| Crop (C) | 1 | § | # | * | # | § | * | * |
| SXC | 1 | # | NS | * | NS | § | NS | § |
| NXC | 4 | NS | NS | # | NS | NS | NS | # |
| SXNXC | 4 | ¶ | NS | NS | NS | NS | NS | NS |
| NXR[S]XC (Error) | 40 | | | | | | | |
| CV | | 23 | 17 | 3 | 45 | 22 | 35 | 8 |

*,§,¶,# = Significant at or < 0.001, 0.01, 0.5, and 0.10 probability levels, respectively
NS = Not significant

Table 3 2 F test significance from ANOVA for yield and yield parameters of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County, 1986-87 growing season

| Source | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spikes $m^{-2}$ | Kernels spike$^{-1}$ | Weight kernel$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| Rep (R) | 4 | NS | NS | NS | NS | NS | NS | NS |
| Nitrogen (N) | 4 | NS | ¶ | § | NS | NS | NS | ¶ |
| RXN (Error) | 16 | | | | | - | - | - |
| Crop (C) | 1 | ¶ | • | • | ¶ | * | * | * |
| NXC | 4 | NS | NS | NS | NS | NS | NS | NS |
| R(NXC) (Error) | 20 | | | | | | | |
| CV | | 30 | 17 | 4 | 17 | 21 | 39 | 13 |

* § ¶ .• - Significant at or < 0 001, 0 01 0 5 and 0 10 probability levels respectively
NS - Not significant

Table 3-3 F test significance from ANOVA for yield and yield parameters of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County, 1987-88 growing season

| Source | DF | Grain yield | Biomass yield | Test weight | Harvest index | Spikes $m^{-2}$ | Kernels spike$^{-1}$ | Weight kernel$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| Rep (R) | 4 | NS | NS | NS | NS | NS | NS | NS |
| Nitrogen (N) | 4 | * | * | * | # | § | § | * |
| RXN (Error) | 16 | - | - | - | - | - | - | - |
| Crop (C) | 1 | ¶ | NS | * | NS | * | § | * |
| NXC | 4 | ¶ | NS | * | NS | NS | NS | * |
| R(NXC) (Error) | 20 | - | - | - | - | - | - | - |
| CV | | 17 | 15 | 70 | 42 | 24 | 30 | 3 |

* §,¶,# = Significant at or < .001, .01, 0.5 and .10 probability levels, respectively
NS = Not significant

crop effect was signficent ($P < 0.001$ .01) for TW SPM KW, KS and TH respectively, and at $P < 0.05$ for GYD

Response Variables

Mean grain yield (GYD), biomass yield (BYD), test weight (TW), and harvest index (HI) along with their respective regression equations are shown in Tables 3.4 through 3.9 In S1 (Tables 3.4, 3.5 and 3.7), the GYD BYD, and TW for both crops responded negatively to incremental N application Harvest index responded negatively for wheat but positively for triticale Comparing the crops at each N level showed differences (LSD = 0.05) only for TW at the 0 and 168 kg $ha^{-1}$ N level

The negative response to applied N in S1 may be the result of residual N mineralized from the previous alfalfa crop The alfalfa, estimated at approximately 10,000 kg $ha^{-1}$ of aboveground biomass (actual data not available) was incorporated on the site in the summer before the study was initiated Although the N content of the alfalfa was not measured, if an estimate of 3% is used, then the above ground portion would account for about 270 kg $ha^{-1}$ of legume N It is believed that the inorganic N applied plus organic N from the legume contributed to an excess of N within the system This is supported by the lodging score, which showed the 0 N rate to be lowest for wheat Lodging was not reflected in the triticale (Table 3.10) Badaruddin and Meyer (1989) also found that high residual N of over 150 kg $ha^{-1}$ from alfalfa grown on clay soils contributed to lodging in subsequent wheat crop In S1, the TW at the 0 N rate (where lodging was lowest) was up to 3.9 kg $hl^{-1}$ higher for

Table 3 4 Response of Florida 301 wheat (W) and Florida 201 triticale (T) to N rates on phosphatic clays at Agrico site Polk County 1986 87 growing season

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 56 | 112 | 168 | 224 | LSD* (p<0 05) |
| Grain yield (kg ha$^{-1}$) | W | 1220 | 970 | 1010 | 1240 | 880 | 362 |
| | T | 1610 | 1210 | 1230 | 1250 | 1160 | 336 |
| Biomass yield (kg ha$^{-1}$) | W | 9530 | 7900 | 8090 | 9150 | 7320 | 1975 |
| | T | 11060 | 8850 | 9130 | 8320 | 8430 | 1670 |
| Test weight (kg hl$^{-1}$) | W | 65 8 | 62 4 | 61 7 | 64 8 | 58 8 | 4 |
| | T | 62 8 | 61 7 | 61 6 | 60 6 | 60 0 | 3 |
| Harvest index (%) | W | 12 7 | 12 2 | 12 5 | 13 4 | 12 0 | 2 |
| | T | 14 6 | 13 6 | 13 5 | 15 1 | 14 1 | 3 |

The LSD values at 0 05 probability level for comparing crop means at the same N rate are: grain yield = 392 biomass yield = 1745 test weight = 3, and harvest index = 3

* Values for comparing means within crop at different N rates

Table 3-5 Response of Florida 301 wheat (W) and Florida 201 triticale (T) to N rates on phosphatic clays at Agrico site Polk County, 1987-88 growing season

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 56 | 112 | 168 | 224 | LSD* (p<0.05) |
| Grain yield (kg ha$^{-1}$) | W | 1150 | 2310 | 3130 | 2690 | 2270 | 547 |
| | T | 1090 | 2110 | 3210 | 3160 | 3360 | 923 |
| Biomass yield (kg ha$^{-1}$) | W | 3420 | 6100 | 8430 | 6950 | 7020 | 1962 |
| | T | 2820 | 5950 | 8000 | 8050 | 8050 | 2542 |
| Test weight (kg hl$^{-1}$) | W | 78.9 | 78.4 | 79.9 | 79.0 | 78.2 | 1 |
| | T | 66.9 | 67.9 | 68.7 | 68.8 | 68.6 | 1 |
| Harvest index (%) | W | 33.6 | 37.8 | 37.1 | 38.7 | 32.3 | 17 |
| | T | 38.6 | 35.4 | 40.1 | 39.2 | 41.8 | 15 |

The LSD values at 0.05 probability level for comparing crop means at the same N rate are grain yield = 699, biomass yield = 2070, test weight = 0.8, and harvest index = 7.0

* Values for comparing means within crop at different N rates

Table 3-6. Regression equations for dependent variables of Florida 201 triticale vs N rate on phosphatic clays at Agrico site Polk County, 1986-87 growing season.

| Dependent variable (Y) | Equation | $R^2$ |
|---|---|---|
| Grain yield (kg ha$^{-1}$) | 1600.0275 + 79.3246$^{ns}$ (N) | 0.24$^{ns}$ |
| Biomass yield (kg ha$^{-1}$) | 11141.8808 + 520.9240* (N) | 0.40* |
| Test weight (kg hl$^{-1}$) | 63.4595 + 0.5548$^{ns}$ (N) | 0.23$^{ns}$ |
| Harvest Index (%) | 14.2031 - 0.7324$^{ns}$ (N) | 0.05$^{ns}$ |
| Spikes m$^{-2}$ | 327.5540 + 18.4038$^{ns}$ (N) - 1.8599$^{ns}$ ($N^2$) | 0.06$^{ns}$ |
| Kernels spike$^{-1}$ | 14.1802 + 0.4880$^{ns}$ (N) | 0.07$^{ns}$ |
| Weight kernel$^{-1}$ (mg) | 35.6402 + 2.8516$^{ns}$ (N) | 0.19$^{ns}$ |

Y = Estimate of dependent variable.
* = Model or slope significant at or < 0.05 probability level.
ns = Model or slope not significant.
N = Nitrogen rate.

Table 3-7 Regression equations for dependent variables of Florida 301 wheat vs N rate on phosphatic clays at Agrico site Polk County, 1986-87 growing season

| Dependent variable (Y) | Equation | $R^2$ |
|---|---|---|
| Grain yield (kg ha$^{-1}$) | 1208.1321 − 37.1837$^{ns}$ (N) | 0.24$^{ns}$ |
| Biomass yield (kg ha$^{-1}$) | 9507.7026 − 291.2913$^{ns}$ (N) | 0.26$^{ns}$ |
| Test weight (kg hl$^{-1}$) | 78.1816 − 1.7302$^{ns}$ (N) + 5.4927$^{ns}$ ($N^2$) − 0.5229$^{ns}$ ($N^3$) | 0.43* |
| Harvest index (%) | 12.4943 + 0.1166$^{ns}$ (N) − 0.0202$^{ns}$ ($N^2$) | 0.08$^{ns}$ |
| Spikes m$^{-2}$ | 872.5104 − 14.8597$^{ns}$ (N) | 0.09$^{ns}$ |
| Kernels spike$^{-1}$ | 4.2834 + 0.7092$^{ns}$ (N) − 0.0666$^{ns}$ ($N^2$) | 0.27$^{ns}$ |
| Weight kernel$^{-1}$ (mg) | 31.6000 − 3.0580§ (N) − 0.4200* ($N^2$) | 0.49§ |

Y = Estimate of dependent variable
*, § = Model or slope significant at or < 0.05, 0.001 probability levels, respectively
ns = Model or slope not significant
N = Nitrogen rate

Table 3-5 Regression equations for dependent variables of Florida 201 triticale vs N rate on phosphatic clays at Agrico site Polk County 1987-88 growing season

| Dependent variable (Y) | Equation | $R^2$ |
|---|---|---|
| Grain yield (kg ha$^{-1}$) | 770.2037 + 479.5520§ (N) | 0.67§ |
| Biomass yield (kg ha$^{-1}$) | 2383.5507 + 1103.2158§ (N) | 0.55§ |
| Test weight (kg hl$^{-1}$) | 66.7692 + 0.3767§ (N) | 0.62§ |
| Harvest index (%) | 33.5826 + 3.0916$^{ns}$ (N) | 0.14$^{ns}$ |
| Spikes m$^{-2}$ | 175.9666 + 21.0075$^{ns}$ (N) | 0.42* |
| Kernels spike$^{-1}$ | 12.7202 + 2.5088$^{ns}$ (N) | 0.38* |
| Weight kernel$^{-1}$ (mg) | 41.4400 + 3.4088¶ (N) | 0.62§ |
| Tiller height (cm) | 72.1228 + 14.3965¶ (N) − 1.5127§ (N$^2$) | 0.69§ |

Y = Estimate of dependent variable
*, §, ¶ = Model or slope significant at or < 0.05, 0.01, 0.001 probability levels, respectively
ns = Model or slope not significant
N = Nitrogen rate

Table 3-9 Regression equations for dependent variables of Florida 301 wheat ve. N rates on phosphatic clays or Agrico site Polk County, 1987 88 growing season

| Dependent variable, Y | Equation | $R^2$ |
|---|---|---|
| Grain yield (kg ha$^{-1}$) | 153 2407 + 1419 6257* (N) 168 2099* ($N^2$) | 0 73§ |
| Biomass yield (kg ha$^{-1}$) | 662 9266 + 2997 9271¶ (N) − 325 6987§ ($N^2$) | 0 61§ |
| Test weight (kg hl$^{-1}$) | 78 1726 + 0 6457§ (N) 0 0996§ ($N^2$) | 0 38* |
| Harvest index (%) | 36 7490 + 0 1868$^{ns}$ (N) | 0 13$^{ns}$ |
| Spikes m$^{-2}$ | 234 3661 + 34 2930* (N) | 0 49§ |
| Kernels spike$^{-1}$ | 14 5101 + 0 7557$^{ns}$ (N) | 0 21$^{ns}$ |
| Weight kernel$^{-1}$ (mg) | 33 8448 + 2 9498¶ (N) − 0 4687* ($N^2$) | 0 54§ |
| Tiller height (cm) | 57 8546 + 18 8620* (N) 2 3397* ($N^2$) | 0 80§ |

Y = Estimate of dependent variable.
* § ¶ * = Model and slope significant at or < 0 05, 0 01 0 001 0 0001 probability levels, respectively
ns = Model or slope not significant
N = Nitrogen rate.

Table 3-10 Lodging score of Florida 301 wheat and Florida 201 triticale at different N rates on phosphatic clays at Agrico site Polk County 1986-87 growing season

| N applied (kg ha$^{-1}$) | Rating score* | |
|---|---|---|
| | Wheat | Triticale |
| 0 | 2 0 | 0 |
| 56 | 4 6 | 0 |
| 112 | 4 0 | 0 |
| 168 | 4 0 | 0 |
| 224 | 4 2 | 0 |
| LSD (0 05) | 1 58 | |

*Rating based on visual score of 0 to 9 where 0 = no lodging and 9 = all tillers lodged

wheat when compared to the other N rates. These results are quite similar to those of Pumphrey and Rubenthaler (1983) who found that TW of lodged wheat grain was 3.10 kg hl$^{-1}$ lower than TW of standing wheat grain. They concluded that the lower TW of the lodged grain was due to the larger percentage of shrivelled grain it contained. It was deduced that this situation also applies to this study. The increase in lodging and decrease in TW found in this study is also consistent to the findings of Roth et al. (1984). Although not intended as a part of this study, the use of legume N in cropping systems is a desired technology which have been well studied (Ladd et al. 1981, Sadaruddin and Meyer 1989, Martin and Touchton 1983, Reddy et al. 1988, Hubbell and Sartain, 1984, Hargrove 1988).

The dependent variables responded positively to incremental N in S2 (Tables 3-5, 3-8, and 3-9). These responses conform to what was expected. The 112 kg ha$^{-1}$ N rate gave highest GYD of 3130 kg ha$^{-1}$ for wheat compared to the 0, 56, and 224 kg ha$^{-1}$ N rates. Triticale GYD responded linearly to N application. Highest numerical GYD to incremental N was at the 56 kg ha$^{-1}$ rate for wheat and at the 112 kg ha$^{-1}$ rate for triticale. Grain yield at these N rates were 1180 and 1100 kg ha$^{-1}$ above 0 N for wheat and triticale, respectively. Biomass yield had a similar pattern and were numerically highest at the 112 kg ha$^{-1}$ N rate for both crops. The 112 kg ha$^{-1}$ N rate also had highest numerical TW which was 79.8 and 58.7 kg hl$^{-1}$ for wheat and triticale, respectively. This N response behavior of TW is similar to the findings of Bruckner and Morey (1988). Highest numerical HI of 38.7 and 39.2 was at the 168 kg ha$^{-1}$ N rate for wheat and triticale, respectively. The increase of HI with applied N rates in this

study (S2 data) was opposite the findings of Eck (1988) who reported a decrease in N1 as N rates increased. In this study both crops performed similarly at all except the 224 kg $ha^{-1}$ level.

The pattern of the variables response to applied N realized in S2 is consistant with those reported in the literature (Bath et al., 1984, Frederick and Marshall, 1985, Nass et al., 1976, Fowler et al., 1989, Black and Siddoway, 1977, Terman, 1979, Mascheno and Walden, 1986, Eck, 1988, Bruckner and Morey, 1988, Chaferr et al., 1988). Stanford and Hunter (1973) reported increase in wheat grain yield up to 135 and/or 188 kg $ha^{-1}$ of N depending on location. Bouquet and Johnson (1987) applied N from 0 to 101 kg $ha^{-1}$ to wheat grown on clay soil over a three year period. They reported a peak rive grain yield increase up to the 101 kg $ha^{-1}$ N rate (well within the range of this study) in two out of the three years.

The lack of response to applied N or the higher rates may be due to luxurious consumption (Bruckner and Morey, 1988) or physiological responses, including toxicity (Fowler et al., 1989; Goyal and Huffaker, 1984).

Yield Components

Tables 3-11 and 3-12 show the mean yield components for the crops. As seen in Tables 3-11, 3-8 and 3-7, in S1 applied N resulted in a slight but nonsignificant increase in SPM for the crops. KS remained about constant for wheat but decreased with increasing N rate for triticale. For both crops KW decreased generally. The excess N in the system as discussed above may have been largely responsible for this response.

Table 3-11 Yield components mean of Florida 301 wheat (W) and Florida 201 triticale (T) in response to N rates on phosphatic clays at Agrico site Polk County 1986-87 growing season

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 56 | 112 | 168 | 224 | LSD* (p<0.05) |
| Spikes m$^{-2}$ | W | 838 | 850 | 859 | 729 | 800 | 242 |
| | T | 342 | 373 | 367 | 368 | 374 | 64 |
| Kernels spike$^{-1}$ | W | 5.2 | 5.0 | 5.2 | 8.6 | 5.0 | 3 |
| | T | 14.2 | 12.2 | 11.4 | 12.3 | 11.5 | 4 |
| Weight kernel$^{-1}$ (mg) | W | 28.3 | 22.9 | 22.6 | 23.2 | 22.5 | 3 |
| | T | 33.5 | 28.0 | 29.9 | 29.9 | 28.3 | 6 |

The LSD values at 0.05 probability level for comparing means at the same N rate are spike m$^{-2}$ = 153 kernel spike$^{-1}$ = 4.3 and weight kernel$^{-1}$ = 4.6

* Values for comparing means within crop at different N levels

Table 3-12 Yield components mean of Florida 301 wheat (W) and Florida 201 triticale (T) in response to N rates on phosphatic clays at Agrico site Polk County 1987-88 growing season

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 58 | 112 | 168 | 224 | LSD* (p<0.05) |
| Spikes m$^{-2}$ | W | 241 | 325 | 430 | 425 | 382 | 118 |
| | T | 201 | 235 | 242 | 307 | 294 | 68 |
| Kernels spike$^{-1}$ | W | 13 8 | 19 0 | 18 8 | 17 7 | 18.0 | 5 |
| | T | 13 1 | 20 5 | 29 3 | 22 1 | 26 3 | 11 |
| Weight kernel$^{-1}$ (mg) | W | 38 2 | 39 0 | 37 8 | 38 7 | 34.8 | 2 |
| | T | 41 8 | 46 2 | 46.8 | 47 8 | 47 4 | 2 |
| Tiller height (cm) | W | 74 2 | 93 7 | 97 2 | 91 2 | 87 8 | 5 |
| | T | 84 8 | 101 2 | 109 4 | 101 2 | 108 0 | 8 |

The LSD values at 0 05 probability level for comparing means at the same N rate are spike m$^{-2}$ = 85 3 kernel spike$^{-1}$ = 8 5; weight kernel$^{-1}$ = 1 9 and tiller height = 6 9

* Values for comparing means within crop at different N levels

Competetively at each N level wheat had more SPM than triticale but the latter had more KS and heavier kernels than wheat

Mean responses and equations for S2 are shown in Tables 3-12, 3-8 and 3-9 For both crops, the components as well as tiller height increased positively with increasing N rate This response conforms to the expected Numerically SPM for wheat was highest at the 112 kg $ha^{-1}$ N rate while KS and KW were highest at the 56 kg $ha^{-1}$ rate However SPM and KW for triticale were numerically highest at the 168 kg $ha^{-1}$ N rate TH for both crops was highest at the 112 kg $ha^{-1}$ N rate Competetively at the respective N levels triticale had heaviet kernels (KW) and taller tillers than wheat However wheat had more SPM at the 112 to 224 kg $ha^{-1}$ N rates KS was higher for wheat at the 112 kg $ha^{-1}$ N rate but highest for triticale at the 224 kg $ha^{-1}$ N rate The response pattern of SPM to applied N in S2 was similar to the findings of Eck (1984) The positive association between KW and applied N in this study (S2) conforms generally to those of Bouquet and Johnson (1987) Brucknet and Morey (1988) also reported positive responses of yield components to increasing rates of applied N

Economic Analysis

This analysis is based primarily on the cost of nitrogen as an input factor Also due to the lack of response to applied N in S1, only data for S2 was analyzed Results of the analysis are shown in Tables 3-13 and 3-14 Highest marginal productivity and marginal value productivity of N was at the 56 and 112 kg $ha^{-1}$ N rate for wheat and triticale, respectively Increase above the 112 kg $ha^{-1}$ N rate resulted in a negative

Table 3-13. Estimated production costs and returns of Florida 301 wheat at various N rates on phosphatic clays at Agrico site Polk County, 1987-88 growing season

| N applied | Grain yield | Marginal productivity of N | Marginal value of N | Marginal cost of N | Total cost of N | Income | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total | Net of N cost |
| kg ha$^{-1}$ | kg ha$^{-1}$ | | $ kg ha$^{-1}$ | | ($) | $ | |
| 0 | 1150 | | | | 0 | 151 80 | 151 80 |
| | | 20 7 | 2 73 | 0 49 | | | |
| 56 | 2310 | | | | 27 44 | 304 92 | 277 48 |
| | | 14 6 | 1 93 | 0 49 | | | |
| 112 | 3130 | | | | 54 88 | 413 16 | 358 28 |
| | | 7 8 | 1 11 | 0 49 | | | |
| 168 | 2690 | | | | 82 32 | 355 08 | 272 76 |
| | | 7 5 | 0 99 | 0 49 | | | |
| 224 | 2270 | | | | 109 76 | 299 64 | 189 88 |

Income calculated on current market price of $0 1320 kg$^{-1}$ based on information obtained from T Hewlett, AREC, Marianna, FL

Table 3-14 Estimated production costs and returns of Florida 201 triticale at various N rates on phosphatic clays at Agrico site Polk County, 1987-88 growing season

| N applied | Grain yield | Marginal productivity of N | Marginal value of N | Marginal cost of N | Total cost of N | Income | |
|---|---|---|---|---|---|---|---|
| | | | | | | Total | Net of N cost |
| kg ha$^{-1}$ | | | $ kg ha$^{-1}$ | | ($) | $ | |
| 0 | 1090 | | | | 0 | 151 87 | 151 87 |
| | | 18 2 | 2 53 | 0 49 | | | |
| 56 | 2110 | | | | 27 44 | 293 92 | 266 48 |
| | | 19 6 | 2 73 | 0 49 | | | |
| 112 | 3210 | | | | 54 88 | 447 15 | 392 27 |
| | | -0 89 | 0 12 | 0 49 | | | |
| 168 | 3160 | | | | 82 32 | 440 18 | 357 86 |
| | | 3 6 | 0 50 | 0 49 | | | |
| 224 | 3360 | | | | 109 76 | 468 08 | 358 32 |

Income calculated on current market price of $0 1393 kg$^{-1}$ based on information obtained from T Howlett AREC, Marianna FL

unit return for wheat (Table 3-13) and negative or the 168 kg ha$^{-1}$ rate for triticale (Table 3-14). The marginal value productivity of N was equal to the marginal cost of N or the 112 kg ha$^{-1}$ N rate for both crops. Numerical dollar value returns (net income over N cost) was also highest at the 112 kg ha$^{-1}$ N rate for both wheat and triticale. The optimum amount of a variable input (in this case N) is that amount which maximizes net income or profit (Hildebrand and Peay, 1985; Taylor et al., 1985). The findings of this study suggest that the 112 kg ha$^{-1}$ N rate is the optimum input level for best returns from small grains on phosphatic slays.

Quality

The quality of a product is often defined by the purpose for which it is used. Wheat has a long history of use in human diets and animal feeds, as well as industrial purposes (Finney et al., 1987). However, the use of triticale, which is a relatively new crop compared to wheat, has been confined mainly to livestock feeds (McGinnis et al., 1985; Myer et al., 1987) although its value as a human dietary ingredient has been under evaluation (Kies and Fox, 1974). Quality in small grains is the sum total of the effects of the environmental conditions and the seed stock on kernel components (Finney et al., 1987). In this study, the quality of the small grains are evaluated with respect to their potential use in livestock feeds.

Test weight, which also functions as a measure of quality, has already been discussed above. Other aspects of quality, as determined by proximate analysis, are presented in Tables 3-15 through 3-23. Due to the significant nitrogen X season and season X crop interactions found in the

Table 3-15 F test significance from combined ANOVA of proximate analysis of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County over two growing seasons

| Source | DF | Fat | Protein | Fiber | Ash | Phosphorous |
|---|---|---|---|---|---|---|
| Season (S) | 1 | * | * | * | * | * |
| Rep (S) (Error) | 6 | - | - | - | - | - |
| Nitrogen (N) | 4 | NS | * | NS | ¶ | § |
| NXS | 4 | NS | * | § | NS | § |
| Rep XN (S) (Error) | 24 | - | - | - | - | - |
| Crop (C) | 1 | NS | * | * | ¶ | * |
| SXC | 1 | * | * | § | § | ¶ |
| NXC | 6 | NS | NS | NS | NS | NS |
| SXNXC | 4 | NS | NS | NS | NS | NS |
| NXR(S)XC (Error) | 30 | | | | | |
| CV | | 5 8 | 4 0 | 6 1 | 6 4 | 3 6 |

* § ¶ = Significant at or < 0 001 0 01, and 0 05 probability levels respectively
NS = Not significant

Table 3 16 F test significance from combined ANOVA of proximate analysis of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County, 1986 87 growing season

| Source | DF | Fat | Protein | Fiber | Ash | Phosphorous |
|---|---|---|---|---|---|---|
| Rep (R) | 3 | NS | NS | NS | NS | NS |
| Nitrogen (N) | 4 | NS | * | ¶ | NS | ¶ |
| RXN (Error) | 12 | | | | | |
| Crop (C) | 1 | § | * | * | NS | § |
| NXC | 4 | NS | NS | NS | NS | NS |
| R(NXC) (Error) | 15 | | | | | |
| CV | | 6 9 | 3 1 | 2 6 | 5 6 | 3 6 |

* § ¶ = Significant at or < 0 001 0 01, and 0 10 probability levels respectively
NS = Not significant

Table 3-17 F test significance from combined ANOVA of proximate analysis of Florida 301 wheat and Florida 201 triticale (crops) in response to N rates on phosphatic clays at Agrico site Polk County, 1987 88 growing season

| Source | DF | Fat | Protein | Fiber | Ash | Phosphorous |
|---|---|---|---|---|---|---|
| Rep (R) | 3 | NS | NS | NS | NS | NS |
| Nitrogen (N) | 4 | NS | * | ¶ | ¶ | § |
| RXN (Error) | 12 | | | | | |
| Crop (C) | 1 | * | * | NS | * | ¶ |
| NXC | 4 | § | NS | NS | ¶ | ¶ |
| R(NXC) (Error) | 15 | | | | | |
| CV | | 4 1 | 4 9 | 6 0 | 6 1 | 3 4 |

* §,¶ = Significant at or < 0 001 0 01, and 0 10 probability levels respectively
NS = Not significant

Table 3.18 Mean fat, protein, fiber, ash, and phosphorous content as percentage of Florida 301 wheat (W) and Florida 201 triticale (T) grain in response to N rates on phosphatic clays at Agrico site Polk County, 1986-87 growing season

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 56 | 112 | 168 | 224 | LSD* (p<0.05) |
| Fat (%) | W | 1.9 | 1.8 | 1.9 | 1.7 | 1.8 | 0.23 |
| | T | 1.8 | 1.7 | 1.7 | 1.5 | 1.6 | 0.09 |
| Protein (%) | W | 18.3 | 19.8 | 20.1 | 18.9 | 20.1 | 0.85 |
| | T | 15.6 | 16.7 | 17.2 | 16.9 | 17.4 | 0.76 |
| Fiber (%) | W | 3.5 | 3.7 | 3.8 | 3.6 | 3.8 | 0.41 |
| | T | 3.3 | 3.3 | 3.4 | 3.4 | 3.5 | 0.25 |
| Ash (%) | W | 2.6 | 2.7 | 2.6 | 2.6 | 2.8 | 0.25 |
| | T | 2.7 | 2.5 | 2.7 | 2.6 | 2.7 | 0.25 |
| Phosphorous (%) | W | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.03 |
| | T | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.03 |

Means calculated on the basis of 100% dry matter

The LSD values at 0.05 probability level for comparing crop means at the same N rate are: fat = 0.08, protein = 0.38, fiber = 0.15, ash = 0.10, and phosphorous = 0.01.

* Values for comparing means within crop at different N rates

Table 3 19 Mean fat, protein, fiber, ash, and phosphorous content as percentage of Florida 301 wheat (W) and Florida 201 triticale (T) grain in response to N rates on phosphatic clays at Agrico site Polk County 1987 88 growing season.

| | | N applied (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 56 | 112 | 168 | 224 | LSD* (p<0 05) |
| Fat (%) | W | 1 5 | 1 6 | 1 6 | 1 6 | 1 7 | 0 09 |
| | T | 1 8 | 1 8 | 1 7 | 1 7 | 1 7 | 0 07 |
| Protein (%) | W | 11 4 | 10 9 | 12 9 | 14 6 | 16 3 | 1 17 |
| | T | 10 3 | 10 0 | 11 2 | 12 9 | 14 8 | 0 62 |
| Fiber (%) | W | 3 2 | 3 2 | 3 2 | 3 2 | 3 0 | 0 13 |
| | T | 3 3 | 3 3 | 3 1 | 3 0 | 2 8 | 0 26 |
| Ash (%) | W | 1 9 | 1 9 | 1 9 | 2 0 | 2 2 | 0 26 |
| | T | 2 2 | 2 2 | 2 1 | 2 2 | 2 2 | 0 14 |
| Phosphorous (%) | W | 0 5 | 0 4 | 0 5 | 0 5 | 0 5 | 0 03 |
| | T | 0 5 | 0 5 | 0 5 | 0 5 | 0 5 | 0 02 |

Means calculated on the basis of 100% dry matter

The LSD values at 0 05 probability level for comparing crop means at the same N rate are fat = 0 05, protein = 0 42, fiber = 0 13, ash = 0 09, and phosphorous = 0 01.

* Values for comparing means within crop at different N rates

Table 3-20 Regression equations for proximate analysis variables of Florida 301 wheat vs N rates on phosphatic clays at Agrico site Polk County, 1986-87 growing season

| Dependent variable (Y) | Equation | $R^2$ |
|---|---|---|
| Fat | 1.903 + 0.015$^{ns}$ (N) | 0.07$^{ns}$ |
| Protein | 18.452 + 0.253* (N) | 0.32* |
| Fiber | 3.456 + 0.059$^{ns}$ (N) | 0.14$^{ns}$ |
| Ash | 2.609 + 0.212$^{ns}$ (N) | 0.05$^{ns}$ |
| Phosphorous | 0.530 + 0.007$^{ns}$ (N) | 0.27$^{ns}$ |

Y = Estimate of the dependent variable
* = Slope and model significant at 0.05 probability level
ns = Model or slope not significant
N = Nitrogen rate

Table 3-21 Regression equations for proximate analysis variables of Florida 201 triticale vs N rates on phosphatic clays at Agrico site Polk County, 1986-87 growing season

| Dependent Variable (Y) | Equation | $r^2$ |
|---|---|---|
| Fat | 1.778 + 0.018$^{ns}$ (N) | 0.34¶ |
| Protein | 15.507 + 0.332§ (N) | 0.62* |
| Fiber | 3.195 + 0.044$^{ns}$ (N) | 0.22$^{ns}$ |
| Ash | 2.638 + 0.007$^{ns}$ (N) | 0.08$^{ns}$ |
| Phosphorous | 0.515 + 0.004$^{ns}$ (N) | 0.14$^{ns}$ |

Y = Estimate of the dependant variable
*,§,¶ = Model and slope significant at 0.001, 0.01, and 0.05 probability levels respectively
ns = Model or slope not significant
N = Nitrogen rate

Table 3-22 Regression equations for proximate analysis variables of Florida 301 wheat vs N rates on phosphatic clays at Agrico site Polk County, 1987-88 growing season

| Dependent variables (Y) | Equation | $R^2$ |
|---|---|---|
| Fat | 1 517 + 0 026$^{ns}$ (N) | 0 18$^{ns}$ |
| Protein | 12 115 + 1 151¶ (N) + 0 314* ($N^2$) | 0 85* |
| Fiber | 3 255 + 0 030$^{ns}$ (N) | 0 24$^{ns}$ |
| Ash | 2 173 + 0 231¶ (N) + 0 040§ ($N^2$) | 0 48§ |
| Phosphorous | 0 444 + 0 008¶ (N) | 0 51* |

Y = Estimate of the dependent variable
* § ¶ = Model and slope significant at 0 001, 0 01, and 0 05 probability levels, respectively
ns = Model or slope not significant
N = Nitrogen rate

Table 3-23 Regression equations for proximate analysis variables of Florida 201 triticale vs N rates on phosphatic clays at Agrico site Polk County 1987-88 growing season

| Dependent variable (Y) | Equation | $r^2$ |
|---|---|---|
| Fat | 1 855 - 0 031$^{ns}$ (N) | 0 54§ |
| Protein | 11 285 - 1 294* (N) + 0 316* ($N^2$) | 0 96* |
| Fiber | 3 449 - 0 091$^{ns}$ (N) | 0 50¶ |
| Ash | 2 199 - 0 005$^{ns}$ (N) | 0 07$^{ns}$ |
| Phosphorous | 0 470 - 0 002§ (N) | 0 52¶ |

Y = Estimate of the dependent variable
*,§,¶ = Model and slope significant at 0 0001, 0 001, and 0 01 probability levels, respectively
ns = Model or slope not significant
N = Nitrogen rate

combined ANOVA (Table 3-15) the data was further analyzed on the basis of individual seasons In S1 (Table 3-16) there was significant ($P < 0.001$) N effect on % protein Crop also had a significant ($P < 0.001$) effect on protein and fiber and on fat and phosphorous at $P < 0.01$ probability levels respectively In S2, (Table 3-17) there was N X C effect ($P < 0.01$ and 0.05) for fat and ash respectively Nitrogen also had an effect on protein and phosphorous at $P < 0.001$ and on fiber and ash at $P < 0.05$ probability levels There was a crop effect on fat protein and ash at $P < 0.001$ probability and on phosphorous at $P < 0.01$ probability

Mean values for the variables within season are shown in Tables 3-18 and 3-19 Tables 3-20 through 3-23 show the respective regression equations In S1 applied N resulted in a linear response in % protein for both crops Fiber ash, and phosphorous also gave positive linear responses whereas fat gave a negatively linear response (Tables 3-18 3-20 and 3-21) Percent protein in wheat was also slightly higher than triticale (Table 3-18) In S2 there was a quadratic protein response to N rates for both crops In triticale, the response of fat fiber ash, and phosphorous was negatively linear However, whereas the response of ash and fiber was also negatively linear in wheat the response of fat and phosphorous was positively linear (Tables 3-19, 3-21 and 3-22) Wheat also had higher % protein compared to triticale at respective N levels (Table 3-19)

Protein is a principal measure of quality in small grains Many researchers have found that protein content increased as N level is increased (Hunter and Stanford, 1973, Nase et al 1976 Tarman, 1979)

Tanaka and Aase, 1987) The response in protein concentration to N application realized in this study is quite similar to those reported by Eck (1988) However, the findings of this study are somewhat opposite to those of Bouquet and Johnsen (1987) who reported no increase in grain protein when up to 101 kg ha$^{-1}$ of N was applied They concluded that foliar disease was responsible for the lack of response It is interesting to note the highest % protein in S1 when grain yield response to applied N was low vs the % protein in S2 when grain yield was higher Haas et al (1976) and Terman (1979) also found this inverse relationship between protein concentration and grain yield According to Finney et al (1957), this is due to the fact that the smaller/shrivelled kernels generally have less or no air pocket compared to more plump ones with larger air pockets Consequently there may not be enough protein to fill the larger pockets in the plump kernels In our study, the size and shape (from observation) of the kernels conform to the above description

The relatively constant % ash (mineral) and % phosphorous may be an indication of the availability of adequate supply of these in phosphatic clays Bouquet and Johnsen (1987) also found that mineral supply (including P) was adequate for wheat grown on a Sharkey clay soil

The nutrient content of wheat and triticale reported in this study in S1 and S2 at all N levels are consistent with those reported in the diets tested by Myer et al (1987) Myer and Barnett (1987) and Ruiz et al (1987), and the protein and phosphorous content in the diet tested by McGinnis (1985)

These similarities suggest that small grains produced on phosphatic clays have the necessary quality to be used for livestock feed

## Summary and Conclusions

Nitrogen may be the only major element limiting small grain production on phosphatic clays in Polk County. A study was conducted over a two-year period to determine yield and grain quality response of Florida 301 wheat and Florida 201 triticale to applied N at five levels (0-224 kg $ha^{-1}$) on these clays. In the first year, N response was masked by carry over legume residual N from a previous alfalfa crop. Second year results showed best overall grain and biomass yields of over 3000 and 8000 kg $ha^{-1}$ respectively were obtained at the 112 kg $ha^{-1}$ N rate for both crops.

Economic analysis showed best net returns also to be at the 112 kg $ha^{-1}$ N rate. N application increased grain protein content but did not affect P content. Quality of grain produced was suitable to be used as animal feeds. The response of the crops was generally (although in some cases numerically different) similar at each N level. Further research should be carried out to determine the effect of timing (split vs. single application), and source of N fertilizer on small grain crops on phosphatic clays.

# CHAPTER 4
# GENERAL SUMMARY AND CONCLUSIONS

Reclamation of waste lands through revegetation often utilizes agricultural plant or crop species mainly because these species are readily available. However most of these species have been bred or selected for production under conditions of high fertility and may not perform well where fertility is marginal, which is often the case with lands needing reclamation. Unlike most land which needs to be reclaimed, however, the 48,000 hectares of mined out phosphatic settling pond clay areas now existing in Polk County, Florida have proven to be very fertile and demonstrate a very high crop production capacity. Phosphatic settling pond clay areas in Polk County results from the phosphate mining industry which for over 50 years has been the "backbone" of the county's economy. The inevitable termination of mining operation in the near future will adversely effect this economy. Small grains on these clays could help the county's economy and improve the production of feed grain in the area. Climatic conditions and poor soil nitrogen may limit production of small grains in the environment.

Two studies were conducted with Florida 301 wheat and Florida 201 triticale over two growing seasons. One study investigated grain filling duration and time of planting while the second study investigated yield

and grain quality response to applied N levels. The crops were attacked by pests and diseases in both growing seasons.

From analysis of the data collected the following was determined:

Grain Filling Duration Study

(1) Planting late vs. early caused a 50% reduction in both grain and biomass yields.

(2) Planting late subjected the crop to high air temperatures during the grain development period.

(3) Late planting shortened the grain filling duration an average of 9.5 days.

(4) Both crops responded similarly to the treatments.

(5) Events during vegetative development may effect the outcome of final grain yields.

(6) Yields realized in the environment are comparable to results from previous research on the crops in other locations.

N Response Study

(1) Residual N from alfalfa may have masked the response to applied N in the first season.

(2) Grain and biomass yields responded positively to applied N (in second growing season).

(3) Both crops gave best grain and biomass yields at the 112 kg $ha^{-1}$ N level.

(4) Net returns were optimized at the 112 kg $ha^{-1}$ N level.

(5) Grain protein had a positive linear response to N level in S1 but responded quadratically in S2

(6) Grain quality compared favorably with that of grains satisfactorily tested in feeding trials

Based on the findings of this study it was concluded that with good management practices e g . timing of activities (planting fungicide and insecticide application) and proper fertilizer program (112 kg ha$^{-1}$ N is suggested), small grains such as wheat and triticale may be successfully produced in the phosphatic clay environment Also, since both crops responded similarly to the treatments the development of production and management guidelines can be similar

Future Research

The findings of this study do not answer all the possible questions pertaining to the production of small grains on phosphatic clays Indeed these results may have only started the process in a series of studies Further research should therefore be carried out in the following areas

(1) Determination of how pre-anthesis (vegetative) developments affect final grain yields e g

(a) the effects of root depth or mass

(b) the uptake and distribution of nutrients per growth stage

(c) nutrients effect on development rate

(2) Nitrogen studies

(a) timing of N application (split vs single)

(b) stage of N application (planting or tillering)

(3) Other management studies

(a) seeding rate and depth

(b) row spacing

(c) no-till vs conventional

(d) water relationships

# APPENDIX

Table A-1 Response of Florida 301 wheat to split application of N fertilizer at Agrico site Polk County, 1986-87 growing season

| Rep | Grain yield | Biomass yield | Spike $m^{-2}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test weight | Harvest Index |
|---|---|---|---|---|---|---|---|
| | kg $ha^{-1}$ | | | | (mg) | (kg hl) | (%) |
| 1 | 1343 32 | 10282 92 | 904 05 | 12 38 | 12 00 | 61 78 | 13 06 |
| 2 | 941 06 | 6676 35 | 784 13 | 4 81 | 24 95 | 63 71 | 14 09 |
| 3 | 1262 13 | 8202 85 | 539 66 | 8 43 | 27 75 | 64 35 | 15 39 |
| 4 | 922 61 | 8940 96 | 885 60 | 3 57 | 29 20 | 61 13 | 10 32 |
| 5 | 756 54 | 7884 13 | 738 00 | 4 58 | 22 40 | 60 49 | 9 59 |
| Mean | 1045 13 | 8397 44 | 770 29 | 6 75 | 23 26 | 62 29 | 12 49 |

Split application of N = 112 kg $ha^{-1}$, applied 50% at planting and 50% at tillering

Table A-2 Response of Florida 201 triticale to split application of N fertilizer at Agrico site Polk County, 1986-87 growing season

| Rep | Grain yield | Biomass yield | Spike $m^{-2}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test weight | Harvest index |
|---|---|---|---|---|---|---|---|
| | ---kg ha$^{-1}$--- | | | | (mg) | (kg hl) | (%) |
| 1 | 1033 32 | 8286 73 | 359 77 | 9 12 | 31 50 | 59 20 | 12 47 |
| 2 | 719 64 | 6475 05 | 378 22 | 9 70 | 19 60 | 56 63 | 11 11 |
| 3 | 1217 85 | 7196 37 | 364 87 | 12 68 | 26 35 | 60 49 | 16 92 |
| 4 | 1376 54 | 10165 50 | 359 77 | 15 18 | 25 20 | 60 49 | 13 54 |
| 5 | 1369 16 | 9930 65 | 392 06 | 10 83 | 32 25 | 63 06 | 13 79 |
| Mean | 1143 30 | 8410 864 | 370 94 | 11 50 | 26 98 | 59 97 | 13 57 |

Split application of N = 112 kg ha$^{-1}$, applied 50% at planting and 50% at tillering

Table A-3 Response of Florida 301 wheat to split application of N fertilizer at Agrico site Polk County, 1997-99 growing season

| Rep | Grain yield | Biomass yield | Spike $m^{-2}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test weight | Harvest index | Tiller height |
|---|---|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | | | | (mg) | (kg hl) | (%) | (cm) |
| 1 | 2706.35 | 6921.80 | 371.20 | 20.14 | 36.20 | 79.79 | 39.67 | 96.03 |
| 2 | 2669.45 | 7157.30 | 506.19 | 14.21 | 37.10 | 79.79 | 37.30 | 93.90 |
| 3 | 2842.55 | 7045.47 | 493.69 | 16.00 | 39.00 | 90.43 | 41.77 | 95.52 |
| 4 | 1581.99 | 3929.30 | 455.57 | 9.99 | 39.60 | 80.44 | 20.21 | 98.42 |
| 5 | 3533.02 | 5591.64 | 466.92 | 19.94 | 37.95 | 78.50 | 63.18 | 92.70 |
| Mean | 2696.67 | 6998.90 | 456.69 | 15.95 | 37.57 | 79.79 | 40.43 | 91.31 |

Split application of N = 112 kg ha$^{-1}$, applied 50% at planting and 50% at tillering

Table A-4. Response of Florida 201 triticale to split application of N fertilizer at Agrico site Polk County, 1987 88 growing season

| Rep | Grain yield | Biomass yield | Spike $m^{-2}$ | Kernel spike$^{-1}$ | Weight kernel$^{-1}$ | Test weight | Harvest index | Tiller height |
|---|---|---|---|---|---|---|---|---|
| | kg ha$^{-1}$ | | | | (mg) | (kg hl) | (%) | (cm) |
| 1 | 4084 14 | 10512 29 | 219 35 | 37 20 | 50 05 | 68 85 | 38 85 | 114 73 |
| 2 | 4216 53 | 9058 46 | 168 73 | 51 18 | 48 80 | 68 85 | 46 52 | 115 77 |
| 3 | 3434 61 | 8051 96 | 292 46 | 22 91 | 51 25 | 69 50 | 42 65 | 107 52 |
| 4 | 4455 64 | 10512 29 | 309 33 | 29 85 | 48 25 | 68 85 | 42 38 | 123 19 |
| 5 | 2942 55 | 9841 29 | 219 35 | 27 86 | 48 15 | 68 21 | 29 90 | 114 30 |
| Mean | 3826 29 | 7703 26 | 241 84 | 33 80 | 49 30 | 68 85 | 40 06 | 115 10 |

Split application of N - 112 kg ha$^{-1}$ applied 50% at planting and 50% at tillering

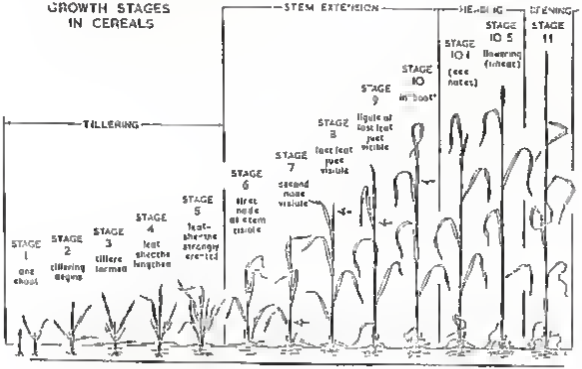


Fig A-1. Growth stages in cereals

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Cassel Samuel Gardner was born and raised in Manchester, Jamaica West Indies. After high school, he attended the Jamaica School of Agriculture where he obtained the Diploma of Agriculture. He was employed as an extension agent with the Jamaican Citrus Growers Association. He later went into agribusiness and worked for the Jamaican firm of Grace Kennedy and Co., Ltd., as a Technical Sales Representative/Sales Supervisor. He subsequently established and operated his own farm and garden store in Linstead, St. Catherine, Jamaica.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

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